PERIPHERAL NERVES AND HAND FUNCTION

The grasping functions of a hand are dependent, not only upon mobility and strength, but also on the ability of the fingers to feel what they are holding, how they are holding it and how strongly they are holding it.

In his excellent monograph, *The Hand*, Charles Bell in 1833 emphasised many of these points at a time when surgery could offer little towards the restoration of hand function. His three chapters, " Of sensibility and touch," " Of the senses generally, introductory to the sense of touch," and " Of the muscular sense," still rank with the most valuable a hand surgeon can read.

The development of physiology during the latter part of the last century introduced means to distinguish between different modalities of cutaneous sensibility. Methods of examination were developed for identifying these modalities. These methods have ever since dominated the neurological examination of sensory function. The extensive work to identify specific receptors in the skin for different modalities led to elaborate theories on the anatomical construction of the receptor system in the skin, which became accepted almost as facts. Progress in surgical technique made nerve suture, too often regarded as synonymous with nerve repair, possible. The results of nerve suture to restore sensory function were described in terms of these tests, developed by physiologists not for this purpose but in order to study receptors.

Sensory recovery after nerve suture was often considered to be satisfactory or even excellent, in terms of these accepted standards. It is to Seddon and his co-workers, who have done more than any others in our time to promote peripheral nerve surgery, that we owe the important distinction between this " academic " recovery and " functional " recovery. " Academic " recovery is judged by the response to the conventional tests for touch and pain, and these neurological methods have been generally considered satisfactory for assessing also the functional value of hand sensibility. This is an entirely different approach from the one always accepted when dealing with other nerve functions. When the sight has to be tested it is felt necessary to find out what the eye can see. When we wish to determine improvement or impairment of the function of the ear we are trying to find out what the ear can hear. When, however, results of nerve suture in the arm and hand have been discussed, it has been exceptional for the examination to go beyond the current tests for the modalities of touch and pain. Function itself has hardly ever been tested.

The same standards have been used to study sensory return to grafts and flaps. The influence of remaining receptors in the bed, of unavoidable but harmful microneuromas, as well as of receptors in the normal skin margins surrounding the transplants has rarely been studied. Conclusions, entirely unsatisfactory from the functional aspect, have been reached.

It has been shown by Walshe, Weddell and many others that the postulated anatomical structures for different modalities seem to be non-existent in the sense which used to be generally accepted. Walshe has stressed that " it is not the least of Woollard's services to science to have redressed the balance between anatomy and physiology in the study of sensory function." Today it must also be questioned whether the sum of the hitherto known modalities is equal to the sensibility as a whole, because it appears that sensibility is a far more complex function than was previously thought. It must now be accepted that the high quality of sensory function which makes it possible for fingers to " see " is a most important issue for hand function, and the current neurological tests for touch and pain cannot tell if this function is present. They cannot distinguish accurately between paraesthesia and sensibility. Paraesthesia, which means low threshold and abnormal response, is not the same as useful sensory function. Paraesthesia may be of value for protection but will never enable a part of a hand to perform a precision-sensory grip. Return of a lower quality of sensory function or, for example, non-independent intrinsic muscle function, can of course still be of value when a more perfect result cannot be obtained. And so, it must be confessed, our present

methods of sensory assessment remain gross and highly unsatisfactory despite the progress that has been made. Improved standards must be found for assessing recovery of nerve function.

It is a welcome sign of progress that in this issue problems are investigated which previously had been regarded as solved. Bowden and Napier suggest tests in order to " provide a simple, repeatable and objective method of assessing prehensile function of the hands as a whole " after peripheral nerve injuries. The article by Mackenzie and Woods shows that of fifty patients in whom the median nerve was sutured at wrist level with the best surgical technique available today only some 50 per cent regained useful function. It may be doubted whether a single one has regained anything close to normal function. Several of the causes of failure are clarified. The paper by Tubiana and Duparc deals with methods other than nerve suture for restoring lost sensory function in the hand, an interesting way to sidestep the nerve problem.

Improved standards will no doubt give rise to improved methods for examining the functional value of peripheral nerve surgery. Better methods of surgery will certainly follow.

Perhaps truth still speaks in the words of Bell when he says " Surgeons, from becoming practically acquainted with a greater number of the phenomena on which physiology is founded than physicians, have perhaps superior opportunities of advancing that science." If it is so, the opportunities must be used.

ERIK MOBERG.

REFERENCES

BELL, Sir C. (1833): *The Hand.* London: William Pickering.

SEDDON, H. J. (1954): Peripheral Nerve Injuries. *Medical Research Council Special Report Series No.* 282. London: Her Majesty's Stationery Office.

WALSHE, F. M. R. (1948): *Critical Studies in Neurology.* Edinburgh: E. & S. Livingstone Ltd.

WOOLLARD, H. H., WEDDELL, G., and HARPMAN, J. A. (1940): Observations on the Neurohistological Basis of Cutaneous Pain. *Journal of Anatomy*, **74**, 413.

THE MANCHESTER SHIP CANAL AND THE COLONIAL FRONTIER

The Seventeenth Robert Jones Lecture delivered at the Royal College of Surgeons of England on December 8, 1960

H. J. SEDDON, LONDON, ENGLAND

I, alas, met Sir Robert Jones but once. My first attendance at a meeting of the British Orthopaedic Association was his last. I remember it clearly. There he sat in patriarchal splendour, surrounded by his favourite sons, Bristow, Girdlestone, McMurray, Platt and Malkin, to name only a few among them. In those days the Association was a small affair, something of a club; its spontaneity was not blighted by a microphone. We youngsters in the back row noted every word, the astonishing wisdom of Sir Robert's remarks, the geniality that softened the blow of a devastating question.

Later we gathered round him—the attraction was quite irresistible—and he asked us about our work with an interest and understanding too genuine, too friendly to be merely flattering. We felt that we were the grandchildren.

With the passage of time these lectures will be given by men who never even met Robert Jones. This will matter little, for none engaged in the practice of orthopaedics can fail to derive inspiration from the life and work of this great and lovable man. To pay tribute to him, however inadequately, in the precincts of this great College is our most coveted honour.

FIG. 1

Robert Jones as a young surgeon. (*By permission of Hodder & Stoughton, publishers.*)

THE MANCHESTER SHIP CANAL

I would like to recall an event in Sir Robert's early professional life, before he became well known. In 1888, when he was only thirty-one, he was appointed Surgeon-Superintendent to the Manchester Ship Canal. That a Liverpool surgeon should have been chosen to organise a medical service for this vast piece of civil engineering was in itself astonishing, for the hostility of Liverpool to its rival's enterprise only stopped short of open warfare.

With the aid of friends at each end of the Canal, Mr Lloyd Griffiths in Manchester and Mr Goronwy Thomas in Liverpool, I have tried to rewrite this part of the Robert Jones story from contemporary records. In this I have had indifferent success, for two reasons. The medical and other journals had little to say. The *British Medical Journal* (1889) and the

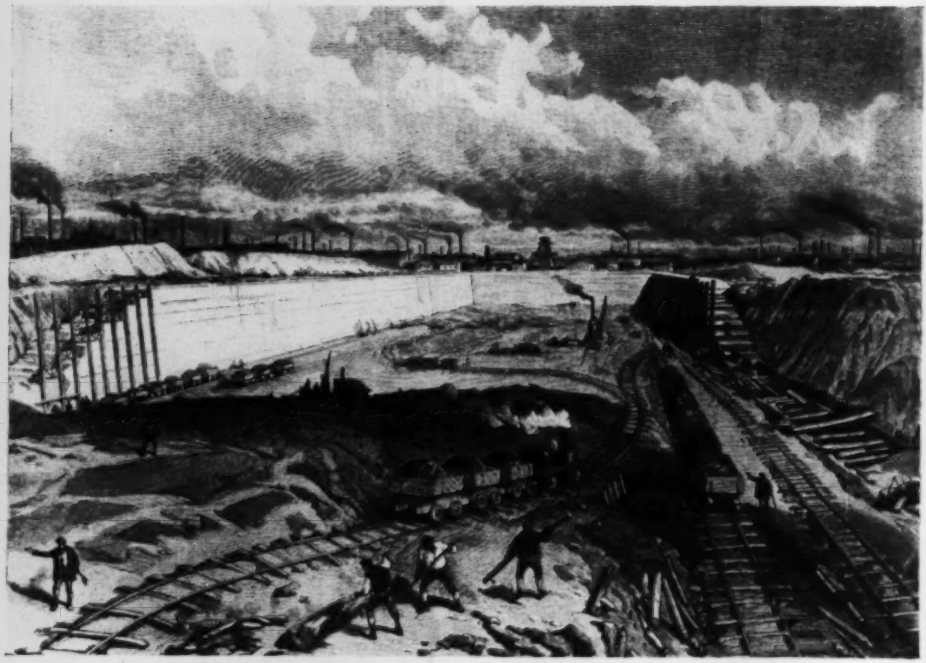


FIG. 2
Manchester Ship Canal: works in progress. (*Illustrated London News*, 1889, August 17, page 200.)

Provincial Medical Journal (1893) alone gave good accounts. The *Lancet*, faithful to the Wakley tradition, was concerned only with the pollution of the water of the Canal. The one history of the Canal, by Bosdin Leech (1907), although referring here and there to accidents, does not mention the organisation for dealing with them. The *Illustrated London News*, which devoted much space to the Canal (Figs. 2 and 3), is equally silent. The relevant records of the Manchester Ship Canal Company, which might well have been a goldmine, have, alas, been destroyed. Mr Goronwy Thomas has allowed me to examine his collection of some seventy-eight tributes published after Sir Robert's death. Many are lengthy, but not one mentions the Ship Canal.

Secondly, Robert Jones himself did not seem to have regarded his work on the Canal as out of the ordinary. He mentioned it almost casually in his application (1889) for appointment to the staff of the Royal Southern Hospital.* The article in the *Provincial Medical Journal* (1893) concludes with the tantalising sentence: " We may expect from Mr Jones in the Journal next year a series of articles on the surgery of the Manchester Ship Canal." They never

* *To the Trustees of the Royal Southern Hospital*

My Lords, Ladies and Gentlemen,

I beg to apply for the post of Surgeon to the Royal Southern Hospital, rendered vacant by the resignation of Mr Paul.

For eight years I have been Surgeon to the Stanley Hospital, where I have acquired extensive and varied experience, which has been still further amplified by my appointment as Consulting Surgeon to the Manchester Ship Canal, involving as it does the supervision of three hospitals, each containing twenty beds.

If honoured by your confidence and elected, it will be my constant effort to worthily perform the function required of me.

I have the honour to be, My Lords, Ladies and Gentlemen,

Yours obediently, Robert Jones.

(*Courtesy of Professor O. H. Williams.*)

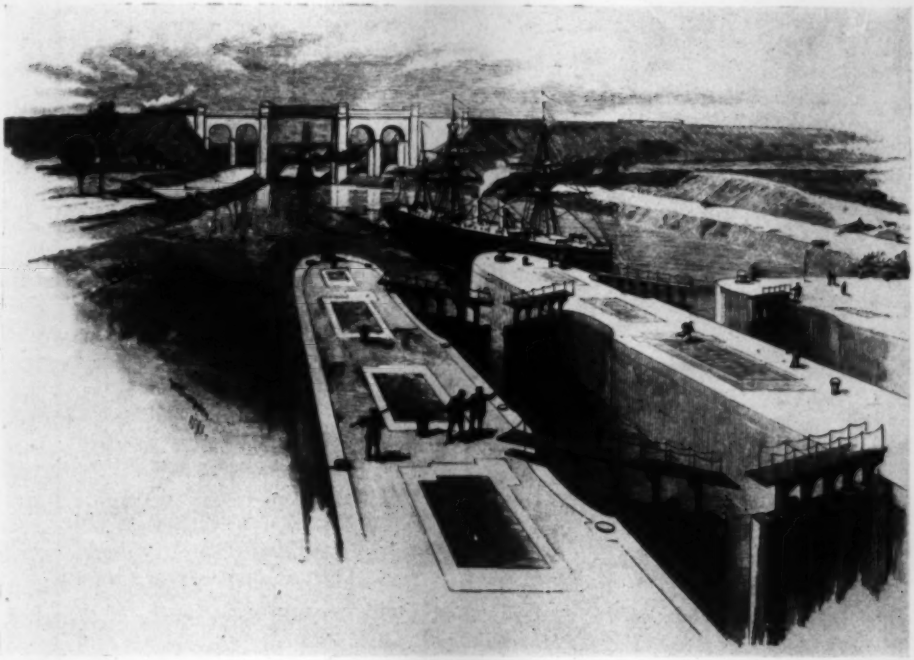


FIG. 3

Manchester Ship Canal: locks and railway viaduct at Irlam. (*Illustrated London News*, 1893, December 30, page 828.) (*Figures 2 and 3 are reproduced by courtesy of the London Electrotype Agency.*)

appeared. Had he not become famous, and had not Watson (1934), in his biography, been at pains to collect information about the Ship Canal affair, the episode might have been completely forgotten.

The salient facts are these. The Manchester Ship Canal, thirty-five miles long, was constructed between November 1887 and November 1893, at a cost of fifteen and a half million pounds. The number of men employed was variously estimated at 14,000 to 20,000. This is what the Manchester folk felt about it when they had paid the bill:

On the Opening of the Manchester Ship Canal

When Orpheus tuned his lyre, he played so well,
The rocks and trees came down the strain to greet;
But thou, Mancunium, with a mightier spell,
Hast drawn great Neptune to thy lordly feet.

New Year's Day 1894 W. BLAKE ATKINSON

As a Manchester man, admittedly rather passé, I applaud these lofty sentiments.

Of the few available accounts of the medical organisation, that written in the *British Medical Journal* (1889) is probably the most accurate: " Our Liverpool correspondent, who, through the kindness of Mr Robert Jones, consulting surgeon to the works of the Manchester Ship Canal, recently had an opportunity of visiting the part of the Canal near Warrington, and of inspecting the hospital at Latchford, writes: . . . The works are divided for medical purposes into eight sections of about four miles each.* A medical man, resident in the neighbourhood, is appointed to each section, his function being to visit at their own homes

* The Liverpool Medical Institution possesses a map showing these sections, but there are nine of them (Fig. 4).

such of the workmen or their families as are sick, and to see them at stated hours at the surgeries which are placed at intervals along the line. There are three hospitals in connection with the Canal, namely, at Ellesmere Port, Latchford, and Barton, intended for the treatment of severe accidents and acute diseases. Each hospital is a substantially built wooden structure. It contains three well-lighted and well-ventilated wards; a general ward, over sixty feet long, a woman and children's ward, and an emergency ward; an operating room, dispensary and splint room; apartments for the resident staff, laundry, and offices, and can accommodate

FIG. 4

A simplified drawing made from the map in the Liverpool Medical ... on which the medical service was based. The approximate ...

twenty patients at a push. It is in charge of a resident house-surgeon, a sister, and a trained nurse. A great number of accidents requiring major operations have occurred since the work began, but there has been a remarkable freedom from infectious outbreaks.* The whole medical service of the Canal is under the direct supervision of the consulting surgeon, who resides in Liverpool. He performs all major operations, and has the care of the cases in the hospitals. The contractor, Mr Walker, takes a kindly and lively interest in the health and well-being of his men, and the completeness of the arrangements he has made for their relief when the victims of accident or disease testifies to his care and skill in organisation. The works give employment to 14,000 men, all of whom pay a weekly sum which partly defrays the expenses of the medical service."

The location of the hospitals and the place names are a little confusing. The *British Medical Journal* gives (from west to east) Ellesmere Port, Latchford and Barton; the *Provincial Medical Journal* names Ellesmere Port, Warrington and Patricroft. This is understandable because Latchford is less than a mile from Warrington, and Patricroft and Barton are contiguous. But at the western end of the Canal Watson places a hospital at Eastham; however, as this village and the locks of the same name are only three and a half miles from Ellesmere Port he may be referring to the first hospital mentioned in the other accounts. He has slipped in giving Latch*field* as the location of the hospital near Warrington.

Only one survivor from this great venture is known to us, Dr J. T. Walker of Old Trafford, Manchester. Watson quotes him at length (pp. 67–69) and he has recently (March 1960) written as follows to Mr Lloyd Griffiths: " I became acquainted with Sir Robert Jones in 1891 when I did a few months' locum for the houseman at the Southern Hospital, Liverpool, where he was on the staff. He offered me a post of House Surgeon for one of the Ship Canal Hospitals, and I went to Barton for two or three weeks at the end of the year when it closed down as the Canal was finished at the Manchester end. Then at the beginning of 1892 I went to Latchford, a suburb of Warrington, and was at the hospital there till the whole of the Canal was done early in 1894. There were three hospitals, the other one being at Ellesmere Port, but I was never there and don't know when it closed. We had plenty of work, as accidents

* This was written before the influenza pandemic of 1890–91.

were very frequent. Sir Robert came regularly, and if necessary he came for the more serious cases when summoned by telegraph, there being no telephone then. There were a great many men, and when an accident happened the patient was brought by the canal-side rail. We always knew when a case was coming as the engine had a special whistle so that the way could be cleared. The hospital had about two dozen beds in the large ward and two or three in a small ward. There were two nurses and the matron. The beds were usually full and patients who were not bad enough for admission came for dressings, etc."

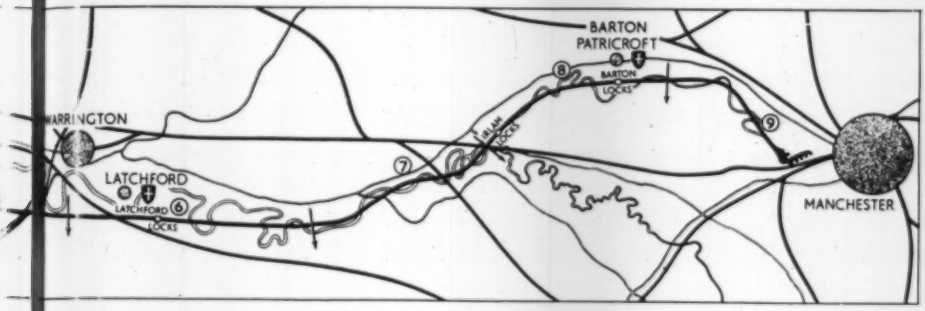


FIG. 4

poo edical Institution showing the divisions of the Canal
roxi ate positions of the three hospitals have been added.

There is no accurate record of the number of accidents that Robert Jones had to deal with. The *Provincial Medical Journal* (1893) gave the figure as " over 3,000." The evidence on their severity is conflicting: " A statement having been made by an official of the Navvies' Union that 1,000 to 1,100 men had been killed during the construction of the Canal, 1,700 permanently injured and 250 partially injured, Mr Bird of the Master Builders Association, in giving evidence before the Labour Commission, gave the correct figures as: 130 killed; 165 permanently injured; 997 slightly injured. For these, ample medical and hospital accommodation had been provided." (Leech 1907).

There can be no doubt that Robert Jones was kept very busy. We must remember that he undertook this work in a part-time capacity, that it called not only for great versatility and courage but for ability to organise and to command the loyal service of a fair number of people. And he was only in his thirties.

I believe that Watson is right in his view that: " For Robert Jones it was like a rehearsal in miniature for what was then not even a cloud the size of a man's hand," the first world war. For this reason alone the medical service of the Manchester Ship Canal deserves to be remembered.

THE COLONIAL FRONTIER

I come now to my second theme. I wonder if you will agree with me that it has some connection with the first. If Robert Jones were alive to-day I think he would be interested in what may be called the frontiers of orthopaedics and the surgeons holding them, many of them men after his own heart. Most of them are young and not well known, though some have already achieved distinction. Many work under conditions that recall the medical service of the Ship Canal. And so that it may not be said that " some there be which have no memorial, who are perished as though they had not been " (Ecclesiasticus, 44, 9) I am going to devote the rest of this lecture to describing these pioneers.

They are all overseas. In this country a young surgeon may start a department from scratch. He may feel isolated, but he can always find a colleague within seventy miles and there are meetings that he can attend from time to time. Furthermore, the social and economic background is fairly uniform; the pattern of development of his work is well established.

It is otherwise in many British territories overseas. One could say much about pioneer work in the older of the great independent countries of the Commonwealth, in India and Pakistan, but time does not permit. They deserve a lecture to themselves. I must limit myself to colonial or recently colonial territories, most of which lie in what our forefathers described as the torrid zone.

TABLE I

NUMBER OF PHYSICIANS BY CONTINENT

Area	Population	Number of physicians	Population per physician
Africa	210,832,000	23,284	9,055
North and Central America	234,276,000	259,664	902
South America	121,000,000	48,263	2,507
Asia, eastern	1,370,821,000	209,688	6,537
Asia, western	82,529,000	16,951	4,869
Europe	619,707,000	665,522	931
Oceania	14,234,000	12,427	1,145
World total	2,653,399,000	1,235,799	2,147

THE BACKGROUND

The way we describe a country of this sort depends on our outlook. The superior white man, still not extinct, calls it *backward*. The business man or economist, thinking of plantations, mines, factories, roads and railways, calls it *under-developed*. The man with no egotism or technical expertise, looking at things dispassionately, realises that the outstanding feature is *poverty*. Not that the people are starving: that is rare nowadays, but the standard of life is low and—this is important for medicine—the revenue of the country is very small by our standards.

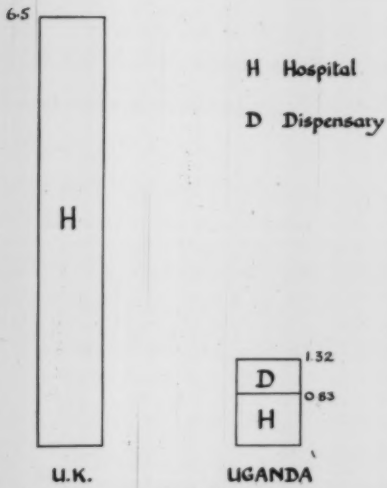


FIG. 5

Hospital beds per 1,000 population; mental hospitals excluded.

Uganda, with some justification, is often regarded as a model country. It is well off in comparison with many other territories. Here are some figures. In 1959 the revenue was 25 million pounds, of which one million pounds was contributed (Colonial Development and Welfare) by the United Kingdom for capital projects. It has been found that, if other equally important services—education, agriculture, animal husbandry, forestry and communications—are not to suffer, the proper allocation for medical services is about 10 per cent; in this country it is about 4 per cent of the total revenue. In Uganda the medical budget for 1959 was 2½ million pounds; the population is six and a half million and this works out at about eight shillings a head compared with £11, 14s. 0d. a head in the United Kingdom—nearly thirty times as much. Let us consider it another way. There are now 400 practising clinicians in Uganda. This number needs to be increased to 900 in order to achieve one-tenth of the ratio in the

United Kingdom. By 1965 Makerere College, which serves the whole of East Africa, may be turning out twenty-five Uganda medical graduates a year. At this rate, if not one of the present clinicians in the country retired or died, it would be 1980 at the earliest before even the modest one-tenth of our ratio was reached. And their salaries must be found too. The fearful lesson provided by certain Latin countries cannot be ignored; if the economic status of the profession is lowered, its standards fall and the public suffers.

One more comparison (Fig. 5). The hospital beds in this country average 6·5 per thousand excluding beds in mental hospitals. In Uganda the figure is 1·32; and it is only 0·83 per thousand if dispensary beds (no nursing, and the patient's relations must bring his food) are excluded. And the burden of sickness is far heavier than here. This is in "prosperous" Uganda.

Conditions on the Ship Canal were similar; sixty beds for what, with the navvies' families, must have been a population of not less than fifty thousand men, women and children. The medical service was for every kind of ill—as much for pneumonia, rheumatic fever and "Russian" influenza as for injuries.

PREVENTIVE SERVICES

Now we come to some of the diseases that the doctor in a tropical country must tackle. The worst scourges are indicated by capitals:

Parasitic disease:	MALARIA
	HELMINTHIASIS
	Trypanosomiasis
	AMOEBIASIS
	Bilharzia
	Filariasis
Spirochaetal, bacterial and virus diseases:	SYPHILIS
	GONORRHOEA
	Yaws
	TUBERCULOSIS
	LEPROSY
	Tetanus
	Smallpox
	TYPHOID FEVER
	Bacillary dysentery
Diseases causing blindness:	Trachoma
	Ophthalmia neonatorum
	Onchocerciasis
Nutritional disease:	Kwashiorkor

It requires no prolonged contemplation of this abbreviated list—it does not include yellow fever or plague—to appreciate that preventive medicine is of the utmost importance in the tropics. Indeed, the greatest triumphs have been in this field: the European now visiting a tropical country, if he observes a few simple precautions, can remain in good health. Some of you, like myself, have visited the cemetery in Calabar to pay homage to Mary Slessor who is buried there. She lived to a good age, but it is sobering to read the inscriptions on many other tombstones. Most of those who lie there died young. It is not very long since tropical Africa and other equatorial regions treated native, settler and visitor with impartial severity.

But this great work of prevention, which demands constant vigilance, has to be paid for out of the modest budget that must cover every kind of medical activity. You may well ask how anything can be spared for curative services.

MEDICAL ORGANISATION

A striking feature of colonial medicine is the part played by local medical auxiliaries under the supervision of a few qualified medical officers. Much of the health work is done by native health inspectors and the less highly trained hygiene orderlies. On the curative side most of the primary medical care is provided at dispensaries or at the more comprehensive health centres. The latter are now replacing dispensaries and they have the following functions: 1) health work and education—for example, housing improvement, water supplies, sanitation, and the control of malaria, tuberculosis and other communicable diseases; 2) domiciliary midwifery; and 3) minor medical treatment. The staff of a health centre may number up to seven people and is entirely indigenous.

REMOTE PLACES
PROVINCIAL HOSPITALS
CAPITAL CITY TEACHING HOSPITAL
SPECIAL UNITS
OPPORTUNITIES FOR AND OBLIGATION TO DO ORIGINAL WORK
SOME KNOW EVERYTHING DO WHAT IS
SPECIALISATION INCLUDING LIMITATIONS IMPERATIVE

FIG. 6
Roles of central, provincial and district hospitals. (*By permission of the Editor of the* East African Medical Journal.)

CURATIVE SERVICES

The man responsible for the minor medical work, the general practitioner in fact, is usually called a medical assistant, and his training is thorough. He treats minor ailments, and refers more serious cases to a medical officer. In Zanzibar there is a remarkable little book, one half of it about what the medical assistant should deal with, the other on the recognition of conditions that should be dealt with at a hospital. In Dar-es-Salaam, the congestion of the out-patient department at the central hospital has been abolished by the institution of well run out-patients clinics in various parts of the town, each staffed by medical assistants and visited daily by a medical officer who sees patients requiring his attention.

Above this widespread system for primary medical care is a three-decker hospital organisation. 1) In the capital city there is a large well equipped hospital, with senior clinicians, called specialists in the colonial medical hierarchy. This is the territorial medical court of

appeal. 2) The country is usually divided into provinces for administrative purposes, and in each there is a provincial hospital where one usually finds a physician, surgeon and obstetrician with appropriate higher qualifications, but not enjoying the status of specialist. 3) In each province there are districts and each has a hospital in direct touch with dispensaries or health centres. The work done in every grade of hospital is of a kind that would tax the versatility and energy of an experienced clinician in this country. Injuries are formidable, malignant disease is often far advanced, tuberculosis is like a great avalanche, the complications of pregnancy are of the greatest gravity. In this welter of appalling morbidity there is little room for therapeutic refinements. Yet it is in this grim environment that these pioneers are doing their work.

The roles of the three types of hospital—central, provincial and district—are illustrated, very simply, in Figure 6 (Seddon 1959). The district medical officer must be expert in dealing with the commoner conditions, even though their treatment may be difficult. Injuries are frequent: fractures, many open and grossly infected; burns, often extensive; and bites, of lions, leopards and snakes, and sometimes human, usually causing severe infection. The man who deals with these things will also have to repair a ruptured uterus or unwind a volvulus. Yet this is only a part of his work. He is responsible for preventive medicine and for public health, but above all he must be a friend of the people and welcome in their homes.

It is the business of the provincial clinician—at the provincial hospital, medicine, surgery and obstetrics are differentiated—to help his district colleagues with the more serious emergencies. One provincial surgeon I know, Keating in Mombasa, runs an efficient flying squad. In addition, the more complex cases are sent to the provincial hospital and here one sees specialisation beginning to take shape. Gillespie in Nakuru, Kenya, deals skilfully with skeletal tuberculosis. Incidentally, there is a ward in his hospital dedicated to Robert Jones. This same surgeon, like Hugh Owen Thomas, has his own workshop and makes apparatus for his patients.

At the central hospital, in the capital city, specialisation is more apparent. Nevertheless, the man with a leaning towards, say, thoracic surgery, important because of the prevalence of tuberculosis, or orthopaedics, important because of the volume of work, often remains a general surgeon. It is better to have two men specialising part time than, say, one orthopaedic surgeon and one general surgeon. It is then possible for the work to be covered if one man is away on tour or on leave; and with two men any tendency to megalomania—not uncommon in specialists—is counteracted. Thus in Nairobi we find a progressive orthopaedic service in the King George the Sixth Hospital, but as a part of general surgery.

Those who work in the central hospital have a responsibility towards the curative services as a whole. They must provide facilities not available elsewhere in the country—in orthopaedics, for example, a workshop for the manufacture of braces and artificial limbs—and they must shape clinical policy. What, in the particular circumstances, is the best way of dealing with tuberculosis? What is the simplest and safest way of treating a fracture of the shaft of the femur? What is the best method for dealing with chronic osteomyelitis? In neural leprosy what type of reconstructive surgery is worth while? There may be special problems, such as fractures, particularly of the spine (Fig. 7), in those who climb oil palms, coconut palms and clove trees. A harness (Fig. 8) (Newman and Wilson 1960) can reduce the hazards of climbing a palm. But no such apparatus is of the slightest use on the fragile branching clove tree; all I could think of for this was a carpet of well stuffed sacks round the tree to break the fall of the unwary.

Here, at the centre, clinicians somehow find time for research, though at the periphery too, where the pressure of work is even greater, I have come across men carrying out clinical trials with commendable precision or engaged in field epidemiology, like Pickles of Aysgarth.

This, roughly, is the pattern in Africa with its great shortage of doctors. In this respect, as in many others, it is the poorest of the continents, as the following table (*Teamwork for Mankind's Well-being*, 1959) shows (Figs. 9 and 10).

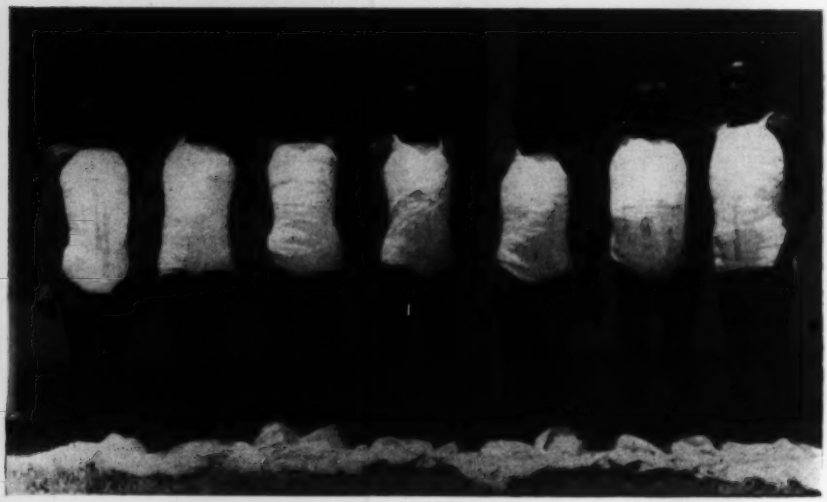


FIG. 7

A few of the patients in the little island of Pemba who broke their spines while picking cloves. These were the fortunate ones; all those who suffered damage to the spinal cord died.

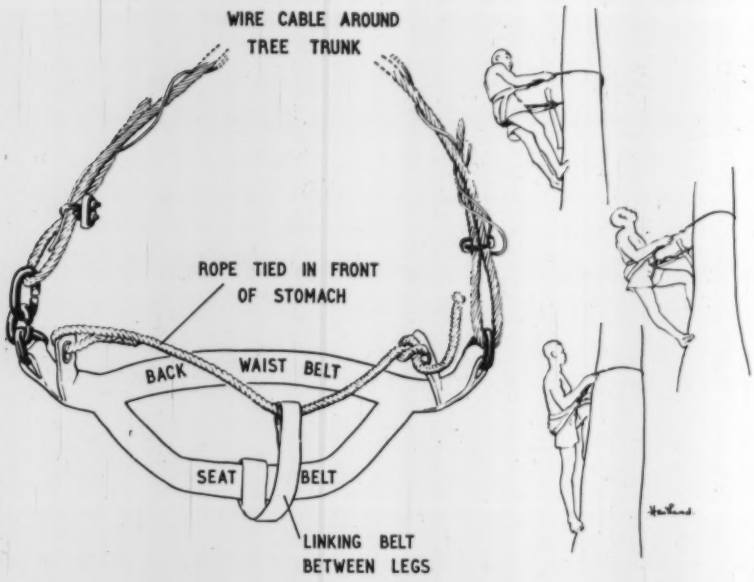


FIG. 8

The harness for the protection of men climbing palm trees devised by Newman and Wilson. (*By permission of the authors and of the Editor of the* British Medical Journal.)

ORTHOPAEDICS

Nevertheless, medicine has become more differentiated elsewhere. Let us consider orthopaedics. In Singapore there is a Chair of Orthopaedics in the University of Malaya; there is a Readership in the University College of the West Indies; there is a Senior Lectureship in the University of Hong Kong; and there are Lectureships in the University of Malta and in the University Colleges of East Africa and of Nigeria. The young surgeon on the Ship Canal would have been glad to know that a number of the men I am describing were Liverpool trained. In addition there are surgeons unconnected with teaching centres devoting themselves wholly to orthopaedics in Malta, Ceylon, Malaya, Singapore, Hong Kong, Mauritius, Nigeria, Southern Rhodesia and the West Indies. There are a few orthopaedic hospitals, similar to those we know so well here. Like ours they have arisen in response to a special need.

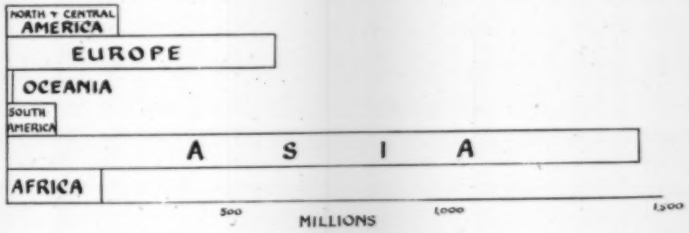


FIG. 9
Population by continents.

FIG. 10
Population per doctor.

May I now take you round the world with glimpses of some of the more notable places? Malta comes first and for me this will always be so for it was there, in 1943 (Seddon, Agius, Bernstein and Tunbridge 1945; Agius, Bartolo, Coleiro and Seddon 1945), that my enthusiasm for this work overseas was aroused. A. J. Craig was its first orthopaedic surgeon and is now Professor of Surgery in Malta's venerable medical school. His able lecturer in orthopaedics is V. P. Amato. Aden has a small medical service, but important in relation to the two Protectorates and to the Yemen. The standard of surgery—including orthopaedics—is high, thanks to the efforts, in recent years, of Arthur Tucker; and the Royal Air Force maintains a medical station of exceptional quality.

In Mauritius the great poliomyelitis epidemic of 1945 (McFarlan, Dick and Seddon 1946; Seddon, Hawes and Raffray 1946) made it imperative to organise an orthopaedic service. The man who took over from me and built it up, during a three-year secondment, was J. M. Fitton of Leeds. André Bathfield, a Mauritian, was the first man to be given an established appointment as orthopaedic surgeon, and he presided over the birth of the splendid Princess Margaret Orthopaedic Centre. He has recently been joined by a fellow-countryman, N. L. Teck Kem (Figs. 11 and 12).

FIG. 11
André Bathfield (*left*) and N. L. Teck Kem, Mauritius.

Two excellent men are in Colombo, Ceylon: G. M. Muller and J. F. Silva.

J. A. P. Cameron was Malaya's first orthopaedic surgeon, stationed in Kuala Lumpur. A. M. Ismail is now working there. In Figure 13 Cameron is in the company of Sir Henry Gurney, that gallant Governor who was murdered by bandits in 1950. The standard of medical care revealed in Figure 14 was achieved within two years of the defeat of the Japanese. Cameron was also the first professor of orthopaedic surgery in the University of Malaya. He was soon joined by a Swedish surgeon, A. G. Karlen (Fig. 15), who had distinguished himself with the Red Cross in Korea. He succeeded Cameron as professor in 1956, and is ably assisted by his lecturer, D. R. Gunn.

In Hong Kong A. R. Hodgson (Fig. 16), Senior Lecturer in Orthopaedics, in collaboration with F. E. Stock, the Professor of Surgery, has made his mark in the radical treatment of tuberculosis of the spine (Hodgson and Stock 1956).

John Golding, Reader in Orthopaedics in the Medical School in the West Indies, deservedly enjoys a reputation extending far beyond the Caribbean. There is no aspect of orthopaedics in the tropics that has escaped him. Farther south, E. L. R. Robertson (Fig. 17) in Trinidad has given that island a very good orthopaedic service.

FIG. 12
Princess Margaret Orthopaedic Centre, Mauritius.

Now across to Africa. The first orthopaedic hospital in the British colonial territories, at Igbobi, just outside Lagos, the Nigerian capital, was established by T. L. Lawson whose early death we still mourn. Then A. F. Bryson (Fig. 18) in Kano provided the first orthopaedic service for the twenty million people in the north, and early this year his orthopaedic hospital was opened (Fig. 19). At Ibadan, in the Department of Surgery, P. G. Konstam (Konstam and Konstam 1958) startled us a little by showing that when hospital beds are too few it is possible to treat spinal tuberculosis effectively by ambulant means.

FIG. 13

Sir Henry Gurney, Governor of Malaya, murdered by bandits in 1950 (*centre*); J. A. P. Cameron (*right*). (*Reproduced by courtesy of the Department of Information, Federation of Malaya.*)

In Tanganyika a start has been made, and under the direction of Walter Kerr in Dar-es-Salaam an orthopaedic department is taking shape.

In Kenya orthopaedics has prospered. In Nairobi Kirkaldy-Willis (Fig. 20), a distinguished pupil of C. V. Braimbridge (Fig. 21), the father of surgery in Kenya, is the head of a flourishing department and, in addition, adviser in surgery for the whole of the country. I have already referred to Frank Gillespie and his workshop in Nakuru and to the versatile Stephen Keating in Mombasa.

In Uganda the policy until recently has been against any differentiation of orthopaedics. At the Medical School in Kampala the surgery of the locomotor system is rightly presented to the African student as a part—it accounts for one-half—of general surgery. Yet the surgeons in Kampala, Ian McAdam, now Professor of Surgery, and his colleagues (Fig. 22) have all made valuable contributions in orthopaedics. Even so Makerere has now appointed its first lecturer in orthopaedics, R. L. Huckstep.

Lastly, the Central African Federation. E. J. Nangle in Salisbury is in demand from Beira to the Copper Belt, and orthopaedics is growing up in Bulawayo too.

It is my good fortune to know all but two of these men, as well as others whom I cannot mention by name because time does not permit.

But it would be unjust to ignore men from countries outside the Commonwealth who, in one capacity or another, are doing good solid work. I found a charming Austrian working alone in a little town on the Kenya coast. He was responsible for everything, and having

FIG. 14
An orthopaedic ward in Kuala Lumpur, about eighteen months after the end of the war against Japan.

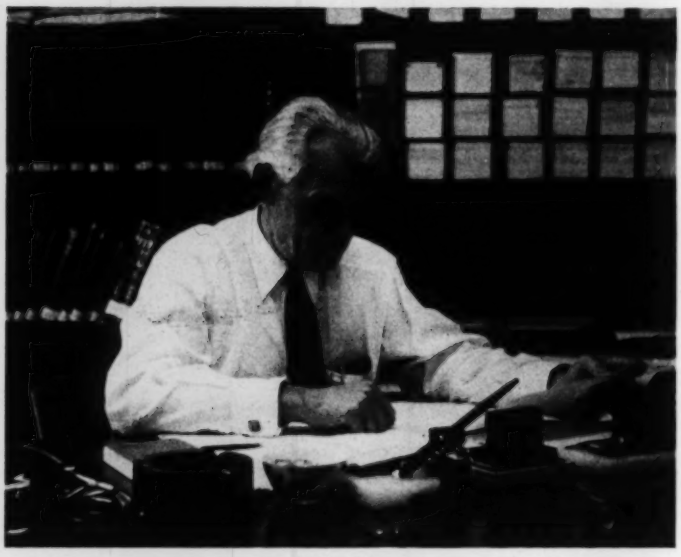


FIG. 15
Professor A. G. Karlen, University of Malaya.

worked at one time with Böhler he treated fractures—without the aid of x-rays—in strict accordance with the inspired word; and he did it very well too.

FIG. 16
A. R. Hodgson, Hong Kong. Walk or ride?

FIG. 17
E. L. R. Robertson, Trinidad.

FIG. 18
A. F. Bryson (*centre*).

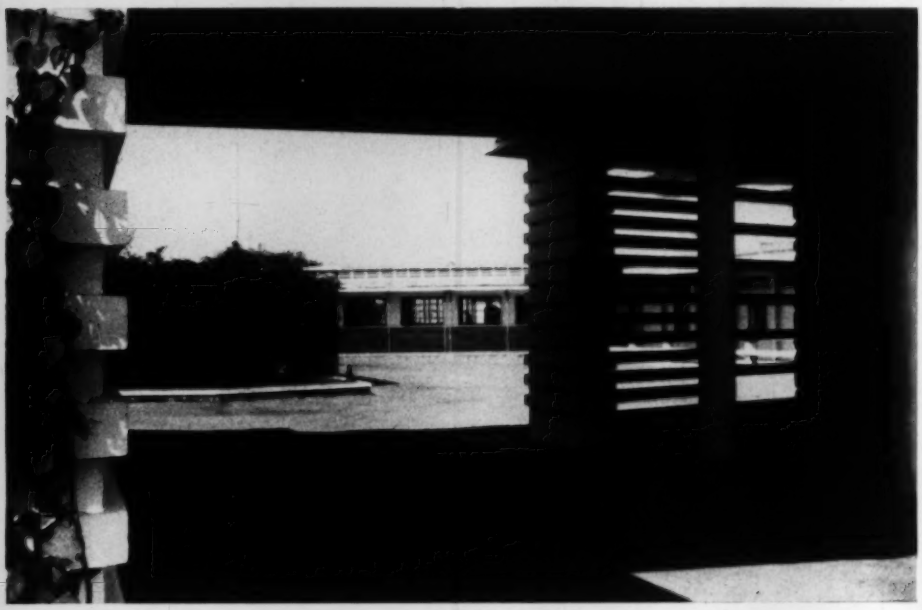


FIG. 19
The new orthopaedic hospital, Kano.

FIG. 20
The staff of the orthopaedic centre in Nairobi in 1952; Kirkaldy-Willis is in the back row at the right.

FIG. 21
C. V. Braimbridge.

FIG. 22
The surgeons at Mulago Hospital, Kampala. *Left to right: standing*, J. Cook, R. L. Huckstep, H. F. Lunn; *sitting*, D. P. Burkitt, I. W. J. McAdam, Professor of Surgery, J. S. Darling.

FIG. 23
H. N. Davies, pioneer in the treatment of pulmonary tuberculosis in East Africa. In 1950, when this photograph was taken, the wards of his hospital at Kibongoto, on the slopes of Kilimanjaro, were no more than thatched shacks erected by patients.

I have seen many of these surgeons at work. I have had the privilege of being responsible for the training of some of them. They are splendid people. They wrestle with a Sisyphean load of work, often with indifferent help and the simplest equipment. In these countries the little hospitals of the Ship Canal exist to-day. Many patients come to them with advanced and hideous disease. Some scourges that we have almost mastered, such as tuberculosis, are still rampant. Yet long before the days of chemotherapy, one of the heroes of medicine in East Africa, Norman Davies (Fig. 23), challenged the prevalent view that pulmonary disease

FIG. 24
Sir Robert Jones, 1857–1933.

in the African could not be treated. Then surgeons there and elsewhere set to work on skeletal tuberculosis, and in this field we must now learn from them. In some places there is even a turn in the tide, as in Hong Kong. The successful treatment of leprosy has opened the door to the reconstructive surgery of the neural form of the disease, of which Paul Brand in India is the greatest exponent.

These surgeons have a shrewd understanding of what is worth while. Their aim is and must be the greatest good for the greatest number. They have an uncommon amount of commonsense.

THE FUTURE

On August 3, 1914, Viscount Grey said: "The lamps are going out all over Europe." To-day the lamps of colonial rule are being extinguished, though in circumstances not of dire tragedy but brightened by faith and hope. An era which with all its faults has brought great benefits to millions of poor people is drawing to a close. Yet it was unnatural, it could not last. The voice of its prophet, Kipling, is no more than a fast-fading echo.

We believe we have found a better way which, we trust, may endure—the association of nations called the Commonwealth. As in a family the ties are mutual respect, understanding, self-sacrifice and common interests. We cannot see far ahead, and our power to influence the future is very limited. But one thing is certain. If we do not lose the love of adventure, the devotion and other-worldliness that animated many of our forebears who helped to build our once great Empire, this country will still gather to itself the loyalty and affection of countless men and women of every race and colour. In this great work we as surgeons have our part to play.

It may seem a far cry from the grime and clangour of canal construction to the silent rivers, the vast lakes, the deserts, the sombre forests, the hamlets and the busy towns of the tropics. But in all the work of the medical pioneer is the same.

And the young man who laboured in obscurity on the banks of the Mersey seventy years ago, and whom we remember today, is the exemplar of other young surgeons who are now his followers in distant lands.

Friends in many countries supplied me with information and illustrations for this lecture. Mr Lloyd Griffiths, Mr Goronwy Thomas, and Mr P. Wade, Librarian at the Royal Society of Medicine, helped greatly in the hunt for records of the medical service of the Manchester Ship Canal. To all of them I gratefully acknowledge my indebtedness.

REFERENCES

(1889): The Hospitals of the Manchester Ship Canal. *British Medical Journal*, **ii**, 288.

(1893): Our Portrait Gallery, Robert Jones, Esq. *Provincial Medical Journal* (Leicester), **12**, 617.

AGIUS, T., BARTOLO, A. E., COLEIRO, C., and SEDDON, H. J. (1945): Clinical Features of the Poliomyelitis Epidemic in Malta 1942–43. *British Medical Journal*, **i**, 759.

HODGSON, A. R., and STOCK, F. E. (1956): Anterior Spinal Fusion. *British Journal of Surgery*, **44**, 266.

KONSTAM, P. G., and KONSTAM, S. T. (1958): Spinal Tuberculosis in Southern Nigeria. *Journal of Bone and Joint Surgery*, **40–B**, 26.

LEECH, Sir Bosdin (1907): *History of the Manchester Ship Canal*. Two volumes. Manchester and London: Sherratt & Hughes.

MCFARLAN, A. M., DICK, G. W. A., and SEDDON, H. J. (1946): The Epidemiology of the 1945 Outbreak of Poliomyelitis in Mauritius. *Quarterly Journal of Medicine*, **N.S. 15**, 183.

NEWMAN, P. H., and WILSON, C. (1960): Harness for Climbing Palm-trees. *British Medical Journal*, **ii**, 596.

SEDDON, H. J. (1959): A Dilettante View of Surgery in Africa. *East African Medical Journal*, **36**, 350.

SEDDON, H. J., AGIUS, T., BERNSTEIN, H. G. G., and TUNBRIDGE, R. E. (1945): The Poliomyelitis Epidemic in Malta 1942–43. *Quarterly Journal of Medicine*, **N.S. 14**, 1.

SEDDON, H. J., HAWES, E. I. B., and RAFFRAY, J. R. (1946): The Poliomyelitis Epidemic in Mauritius in 1945. *Lancet*, **ii**, 707.

UNITED STATES GOVERNMENT AND WORLD HEALTH ORGANIZATION (1959): *Teamwork for Mankind's Well-being*. Washington, D.C.: U.S. Government Printing Office.

WATSON, F. (1934): *The Life of Sir Robert Jones*. London: Hodder & Stoughton Limited.

TENDON GRAFTING

Illustrated by a New Operation for Intrinsic Paralysis of the Fingers

PAUL W. BRAND, VELLORE, INDIA

Professor of Orthopaedic Surgery, Christian Medical College and Hospital, Vellore

A free tendon graft always becomes adherent. A tendon in living continuity with its muscle may develop a new gliding path completely free of adhesions after being transferred. A free graft, because it has to acquire a new blood supply, has to become connected to the surrounding structures. One should, therefore, choose to transfer rather than graft a tendon, when other considerations do not limit one's choice, such as there being no unparalysed muscle with a tendon long enough to reach the required insertion, or that the transfer of a suitable tendon would leave a weakness in the donor function. Again, in operations to balance the muscle power of the fingers, the muscles that move the wrist are a valuable source of power, but they have to be lengthened by a tendon graft.

The adhesions that occur after a tendon graft limit the movement of the tendon in proportion to their density, and in inverse proportion to the mobility of the normal structures to which they are attached. Although their differences are mainly of degree they may be considered in two groups: scar adhesions and blood vessel adhesions. The former are rigid and crippling, while the latter vary in their effect, and will stretch after operation to allow fair mobility.

Scar adhesions—Every wound heals with a scar. The scar is common to the whole wound and connects each and every structure in the wound. The density of the scar varies with the skill of the operator, with the amount of local trauma, and with the presence or absence of haematomata and infection. This scar, whether it is thick or thin, causes a direct adhesion between every immobile structure that has been divided in the wound and the structures which are planned to move.

The worst adhesion of all is that which grows from a tendon anastomosis; it is a product not of the graft but of the living motor tendon. Bunnell (1932) has vividly described its nature, and calls it a pseudopodium which grows out from an " unsatisfied " end of a tendon. Bunnell emphasises the importance of ensuring that every fibre of tendon that has been cut should be " satisfied " by immediate attachment to another cut surface, whether tendon or bone. When operating after a previous reconstruction has failed, we have often had the humbling experience of confirming the accuracy of Bunnell's description. Even after careful end-to-end suture of tendons, it is sometimes found that a stray fibre has escaped the suture line to form an anchor. An adhesion from the unsatisfied end of a tendon is so crippling because of the purposeful way in which it grows on and on, like the tendril of a vine that is seeking support, until it attaches itself to a rigid structure. Once anchored, the growing fibre thickens and contracts and draws the tendon anastomosis towards this new insertion, to rob the tendon graft of all mobility.

It is very difficult to avoid an unsatisfied end of a thick motor tendon when a thin graft is being attached to it. Under such circumstances Bunnell has suggested " bird-beaking " the thicker tendon to reduce its diameter, and Pulvertaft (1956) has used adjacent structures such as the lumbrical muscle belly in the palm to cover the anastomosis. A new method of tendon anastomosis which eliminates the danger of the unsatisfied end is described below.

Blood vessel adhesions—Suppose that no rigid structure has been divided and that a free graft lies in a snug tunnel that has been bloodlessly created by the gentle pressure of a blunt-nosed tunneller in a connective-tissue plane. Even under such ideal circumstances the graft cannot live without the blood vessels that must grow into its surface from the surrounding tissue.

These vessels, although easier to stretch than the scar tissue, constitute a drag on the tendon, and without disciplined exercises after operation they may greatly limit movement.

Final range of movement—In the absence of rigid adhesions the final range of movement obtained by a tendon graft is determined by two factors: the movement allowed by the length and stretch of blood vessel adhesions, and the movement of the adjacent tissues to which these adhesions are attached. Though it is difficult to separate these two factors in any one case, we have recently demonstrated in a series of experiments in monkeys that in many successful grafts the second factor has accounted for the greater part of the movement. The nature of the tissues lining its path may decide success or failure to a greater extent for a tendon graft than for a tendon transfer.

In addition to the basic rules for tendon transfers (Mayer 1916) there are, therefore, rules which are of special importance for tendon grafting. 1) Scarring must be kept to the least possible by atraumatic technique and careful haemostasis. 2) The extent of the scar should be kept small by the use of small incisions with tunnels made by a blunt instrument between them. Fortunately in tendon grafting it is usually possible to do the tendon anastomosis outside the limb without raising a flap. The motor tendon is brought out through a proximal transverse incision. The graft, after attachment to the motor tendon, is passed through a tunnel to its insertion, pulling the anastomosis behind it into an undamaged gliding plane away from the incision. This is not possible in direct tendon repair, where the anastomosis has to lie in the wound of access. 3) Mobile structures must surround the tendon graft. Conversely, no rigid structure should be divided or even scratched in the same wound as a tendon graft. When a tendon has to pass near bone, ligament or retinaculum, or between fibrous septa linking the skin to a deeper, immobile plane, the tunnel should be made gently by the blunt-nosed tunnelling forceps (Fig. 1). The surgeon must practise the patience of an earthworm feeling its way between roots and stones, and he must not force a way through rigid structures or the tunnel will not be lined with yielding material. The closeness of a rigid structure does not matter, so long as it is not wounded. Most rigid structures are surrounded by an almost invisible layer of slippery tissue, which, if it has not been scarred, is remarkably elastic. It is the unavoidable proximity of rigid structures in the flexor sheath of the finger that makes this area a difficult problem, with its own special rules. Here we follow Pulvertaft's (1956) method. 4) Tunnels must not be made larger than necessary. It is false reasoning to expect extra space to allow greater freedom for the graft, for this extra space becomes filled with scar, which will allow less mobility than almost any intact tissue.

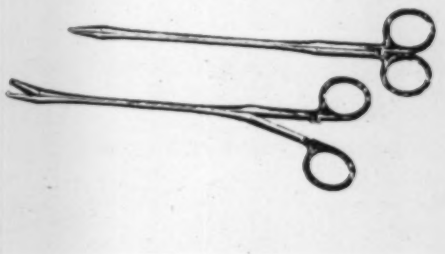


FIG. 1
Tendon tunneller (J. G. Andersen).

TECHNIQUE OF ANASTOMOSIS OF TENDONS OF UNEQUAL THICKNESS

Crippling adhesions grow from the cut end of a tendon. A longitudinal slit heals with almost no adhesions. The following technique is based on the principle that all cut ends may be wrapped up in sheets made from opened-out tendon (Fig. 2).

Most tendons are easily opened into flat sheets, without damage to their gliding surfaces, and many tendons possess the structure of a rolled-up sheet. The free edge of the sheet is marked by a visible cleft or hilum on the deep surface of the tendon into which fatty, elastic strands carry nutrient blood vessels. If a knife blade is slipped along such a cleft the tendon

can be opened out and unrolled. Even if a natural plane of cleavage is not obvious, a thick tendon may be slit open and a tendon graft may be laid inside it and stitched in position, after which the stouter tendon is rolled up, and the edges are held together by a running filament of 45 gauge stainless steel wire.

If more than one graft is to be attached to one motor tendon the end of each may enter the opened-out motor tendon through a separate longitudinal slit so that not more than one thickness of graft is lying in one part of the motor tendon. When it is important to have a uniform thickness and no bulge, a small part of the inside of the motor tendon is excised so that the total bulk of motor tendon and graft is the same as that of the original motor tendon.

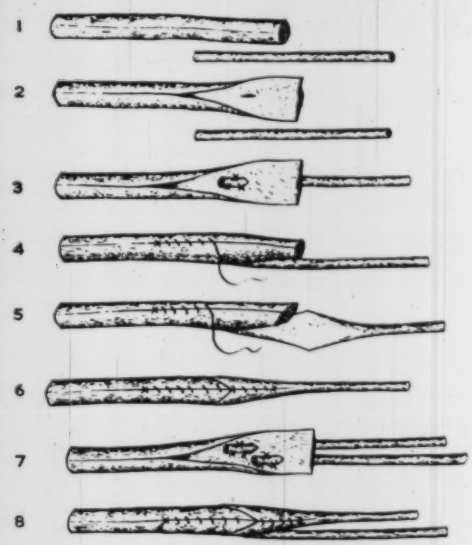


FIG. 2

Steps in the wrap-around method of tendon anastomosis. 1–6—Motor tendon and slender graft. 7–8—Motor tendon with two grafts.

The cut end of the motor tendon is then enclosed in the graft, which is opened out at the point at which it crosses the end of the motor tendon. If a thick graft has been used it may be slit open in the same way as the motor tendon. The best tendons for grafting are those of the plantaris and palmaris longus muscles, which are so thin that they possess no hilum but obtain their blood supply through the surface of the tendon; and they possess the peculiar property of a very large degree of lateral extensibility. Pilcher (1939) observed this property of the plantaris tendon when using it to repair hernias. The edges of the average plantaris can be pulled apart with needle-pointed forceps, without the use of a knife, into a sheet two inches wide. The end of the stoutest motor tendon can be completely engulfed by this beautiful glistening membrane, by suturing the edges together with 45 gauge stainless steel wire. When the anastomosis is complete no cut end of either graft or motor tendon should be visible in the wound. By cutting the motor tendon obliquely, the anastomosis tapers down gradually to the thickness of the graft.

We have recently developed a quick and simple method of removing a plantaris or palmaris tendon through one small incision. A stripper eighteen inches long terminates in an eye, a quarter of an inch in diameter, with a cutting edge (Fig. 3). The tendon is divided

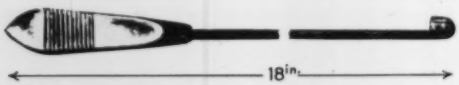


FIG. 3

Tendon stripper.

at its insertion and threaded into the eye of the stripper. The limb is held straight at the elbow or knee and the tendon kept stretched, while the stripper is thrust firmly up the limb until it cores out the tendon from inside the muscle, because all the muscle cannot pass through the eye. The tendon is then withdrawn through the incision. Bleeding is negligible and most patients from whom the plantaris has been taken are able to walk without pain within three or four days.

The plantaris has an abundant paratenon which should be stripped back from the cut end in the form of a sleeve when an anastomosis is being done. This sleeve can then be rolled back to cover the suture area.

OPERATION FOR CLAW HAND

A good example of the value of tendon grafting is in intrinsic paralysis of the hand. In a previous communication (Brand 1958), in which we analysed the results in 564 fingers of the sublimis transfer operation of Stiles (1922) and Bunnell (1942), it was pointed out that the operation is a very powerful corrective for intrinsic paralysis of the fingers, but that the chief defect is the production of the opposite deformity—intrinsic overaction—in many patients. The reason for this is that the prime flexor of the proximal interphalangeal joint is removed and used as an extensor of the same joint. It seems that a finger with intrinsic paralysis cannot really spare its flexor sublimis, and that in the absence of this muscle as a flexor, it is too powerful to be used as an extensor.

We are now using a wrist-moving muscle extended by a many-tailed free graft for correction of intrinsic paralysis. At first toe extensor tendons were used as grafts and a flap was raised on the dorsum of the wrist for the anastomosis. Later the plantaris tendon and occasionally the palmaris were used and the need for the flap has been avoided by doing the operation entirely through short transverse incisions proximal and distal to the area of anastomosis. The grafts, after crossing the wrist, pass separately through the interosseous spaces along the route suggested by Fowler (1949), anterior to the deep transverse metacarpal ligament; they are sutured to the edge of the lateral band and dorsal expansion of each finger, proximal to the proximal interphalangeal joint. The tendon is inserted on the ulnar side of the index finger and on the radial side of the middle, ring and little fingers. The tendon to the little finger is usually passed through the third interosseous space and across the fourth metacarpal bone in the palm.

Recently the extensor carpi radialis longus has been used as the motor. It has been brought around the forearm and the grafts have been passed through the carpal tunnel.

Technique of operation—The extensor carpi radialis longus or brevis is divided at the distal end of the radius through a short transverse incision. It is withdrawn through a second transverse incision three and a half inches proximally, and laid on a wet towel. It is slit open along a natural plane of cleavage and the proximal ends of the tendon grafts are stitched to its inner surface. The tendon is then closed up around the ends of the grafts using a running stitch of 45 gauge stainless steel wire. One of the grafts is then stretched into a sheet and wrapped around the motor tendon, its edges held in position by the same filament of stainless steel wire. Tendon tunnelling forceps are then introduced at the first incision and passed subcutaneously to the proximal incision where the ends of the tendon grafts are grasped and pulled through so that the anastomosis lies under intact skin. Through dorsilateral incisions in the proximal segment of each finger the lumbrical tendon and lateral band are identified, and the tendon tunnelling forceps are now passed from this point through the palm to grasp a strand of tendon graft and withdraw it into the finger. Great care must be taken in this tunnelling process. The nose of the tunneller must first identify with certainty the deep transverse metacarpal ligament and pass it on the volar side for about half an inch. The handle of the tunnelling forceps is then lowered until it points dorsally in order to feel for a weak point in the interosseous membrane, through which the tunneller is thrust into the wound on the dorsum of the wrist. When all the tendon grafts are in position they are stitched at equal tension, suturing first the index finger and then the little finger and then the intermediate fingers. The tension chosen is such that the tendons are completely relaxed when the wrist is dorsiflexed 45 degrees, the metacarpo-phalangeal joints are flexed to 70 degrees, and the interphalangeal joints are straight (Fig. 4). This position is maintained for three weeks in a light plaster cast.

Re-education after operation—Although the late results of this operation are better than those of the sublimis transfer, the re-education is more difficult. It is most important not to allow

the fingers to rest in the claw position during the period of re-education. We recommend splinting each finger with plaster or plastic gutter splints in the straight position, encouraging free metacarpo-phalangeal movement with resisted active extension of the wrist. The finger splints should be removed and reapplied daily until education is complete.

Defects in the operation—One defect of this operation is that dorsiflexion of the wrist slackens the graft. Therefore in re-education the patient has to prevent dorsiflexion while he contracts his dorsiflexor, which is difficult. The second defect is that adhesions are likely at the point where the graft perforates the interosseous membrane. As this point is distal to the wrist only a small range of tendon movement is necessary and therefore the result is satisfactory in spite of the adhesions. Both of these difficulties are overcome by the use of an alternative route we have been using recently.

Alternative route—The extensor carpi radialis longus tendon is used, detached at its insertion and withdrawn halfway up the forearm. It is then tunnelled deep to the brachioradialis to an incision on the front of the forearm three inches proximal to the wrist. The anastomosis to the grafts is now carried out. The tunneller is then introduced through a midpalmar incision and passed through the carpal tunnel into the forearm to bring the grafts into the palm, leaving the anastomosis proximal to the carpal tunnel. From this point each strand of graft is separately passed on to its finger destination (Fig. 5).

FIG. 4

FIG. 5

Figure 4—Diagram showing the path of a tendon graft from the extensor carpi radialis brevis, through an interosseous space. Figure 5—Diagram showing the path of a tendon graft from the extensor carpi radialis longus, through the carpal tunnel. Re-education is easier when this route is used.

We have used this route (reported by Littler in his Case 6–b, 1949) in some of our recent operations, about ten of which are included here. We have found that although re-education after operation is somewhat easier than in the other method, there is sometimes a limitation of dorsiflexion of the wrist which weakens the grasp. There is also a theoretical danger that crowding the carpal tunnel may endanger the median nerve.

The flexor carpi radialis has also been used, extended by free grafts through the carpal tunnel, but the results have not been so good.

MATERIAL

Eight hundred and sixty-one clawed fingers in 246 hands have had tendon grafts using the extensor carpi radialis brevis as the motor muscle. All patients had leprosy, of whom fifty-three had a pure ulnar paralysis and 183 had a high ulnar and low median paralysis.

METHOD OF ASSESSMENT

We have used the same assessment as before (Brand 1958), but there has been a more critical interpretation of the terms " excellent " and " good." Measurements of the range of active, assisted, and passive movements of the fingers, and photographs in six standard positions, were taken before and after operation and again later during observation, so that each patient had eighteen standardised photographs (Fig. 6). The average length of observation

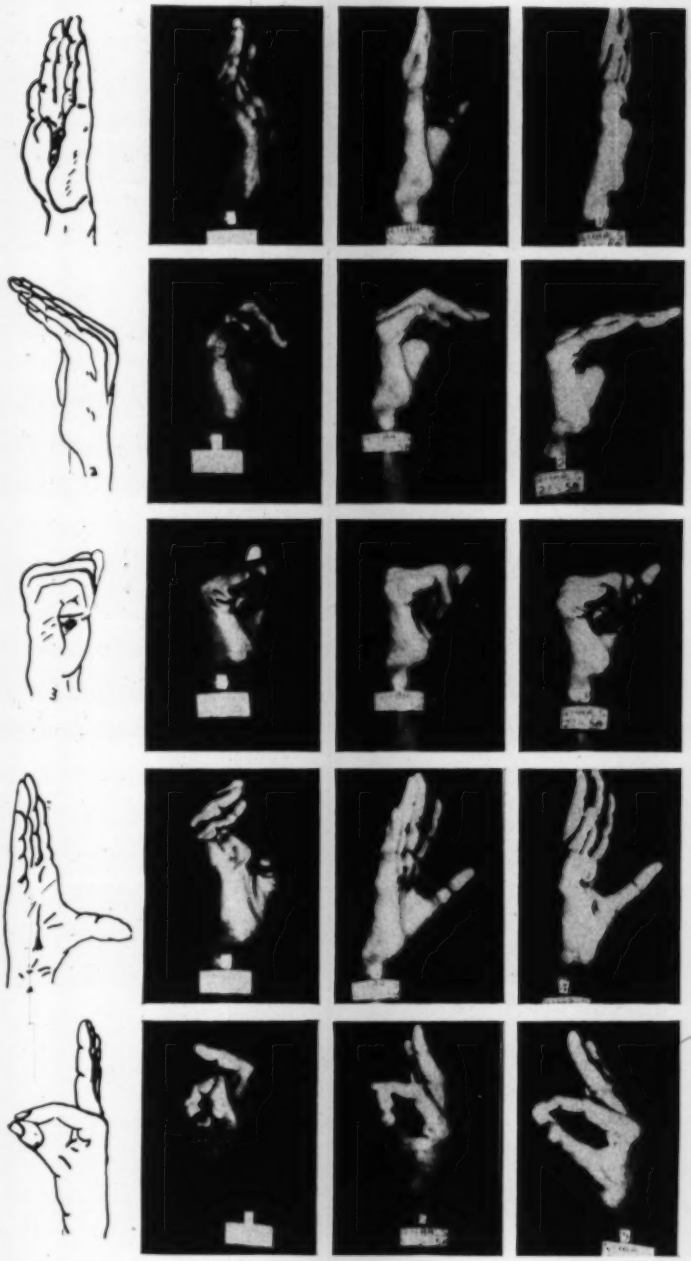


FIG. 6

A typical photographic record as used in every patient. The first column shows the diagram for imitation. The first photograph is the attempt before operation, the next that after operation, and last, the final result usually two or more years later.

in this series is two years. It had been observed in the patients in whom the sublimis had been used that, although after operation the hand could achieve the lumbrical position and could open out fully there was frequently a difficulty in flexing the interphalangeal joints without previous flexion of the metacarpo-phalangeal joints; that is, it was impossible for the patient to put his hands into the old claw or " hook " position. This disability was not recorded in the sublimis assessment (Brand 1958) but a new assessment on the " hook "

TABLE I

FULLY OPEN HAND ASSESSMENT IN 861 FINGERS

Operations		Excellent		Good		Fair		Poor	
Finger	Number	Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent
Index	185	90	49	60	32	33	18	2	1
Middle	191	90	47	66	35	31	16	4	2
Ring	243	118	48	87	36	36	15	2	1
Little	242	126	52	78	32	36	15	2	1

TABLE II

LUMBRICAL POSITION ASSESSMENT IN 861 FINGERS

Operations		Excellent		Good		Fair		Poor	
Finger	Number	Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent
Index	185	72	39	74	40	37	20	2	1
Middle	191	72	38	78	41	38	20	3	1
Ring	243	98	40	107	44	35	15	3	1
Little	242	120	50	89	37	30	12	3	1

TABLE III

HOOK POSITION ASSESSMENT IN 861 FINGERS

Operations		Excellent		Good		Fair		Poor	
Finger	Number	Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent
Index	185	132	71	24	13	23	13	6	3
Middle	191	138	72	18	9	26	14	9	5
Ring	243	164	67	33	14	32	13	14	6
Little	242	166	69	33	13	32	13	11	5

position is included here. In Table V, "mechanics of closing" means the correct sequence of joint movement in making a fist.

After operation a hand to be called excellent must be able: 1) to open fully and freely at all joints with no degree of flexion limitation and with no hyperextension of the proximal interphalangeal joints and flexion of the terminal interphalangeal joints (intrinsic overaction Table I), 2) to flex at the metacarpo-phalangeal joint without flexion at the interphalangeal

joints (lumbrical position Table II), 3) to flex at the interphalangeal joints without flexion at the metacarpo-phalangeal joints ("hook" position, Table III), 4) to close the fist fully with the finger tips tucked in (Table IV), 5) to open the hand without lateral deviation of the fingers or hyperextension of the metacarpo-phalangeal joints, 6) to achieve separate lumbrical movement of each finger, that is, each finger must be able to flex at the metacarpo-phalangeal joint without flexing the interphalangeal joints while the other fingers remain straight (Table V).

TABLE IV

CLOSED FIST ASSESSMENT IN 246 HANDS

Excellent		Good		Fair		Poor	
Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent
145	59	42	17	51	21	8	3

TABLE V

MECHANICS OF CLOSING IN 246 HANDS

Excellent		Good		Fair		Poor	
Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent
217	88	20	8	9	4	0	0

TABLE VI

FINAL ASSESSMENTS IN 246 HANDS

	Excellent		Good		Fair		Poor	
	Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent
Appearance . .	62	26	112	45	68	27	4	2
Function . .	107	43	81	33	54	22	4	2
Patient's statement	64	26	119	48	59	24	4	2
Overall total . .	60	24	115	47	67	27	4	2

It is perhaps surprising that individual lumbrical action is possible when a single muscle has been used for all four fingers. The fact that this is so reminds us that most of the movements of the fingers are powered by forearm muscles while the intrinsic muscles provide the balancing tone, which at finger level requires only a small amplitude. In a hand rated excellent, therefore, there is no abnormality in appearance or activity except that voluntary abduction and adduction of the fingers is not possible (Table VI, Fig. 7).

RESULTS

Even with the more critical standards of evaluation used in this study the final results as shown in Tables I to VI are substantially better than those of the sublimis transfer operation. Twenty-four per cent achieved an excellent result, 71 per cent achieved an excellent or good result and in only four hands was the result poor. These four, on further analysis, showed that the poor result was caused in one hand by a pre-operative defect in the extensor tendons and destruction of the dorsal expansion over the proximal interphalangeal joint, and in another by dislocation of the extensor tendon in the interphalangeal gutter. A third developed

FIG. 7

FIG. 8

Figure 7—A good result, three years after operation. Note slight bow-stringing of the graft on the back of the wrist on dorsiflexion.

Figure 8—Bilateral claw hands which had a sublimis transfer on the right hand in 1951 and a many-tailed graft on the left hand in 1957. Here the hands are held in the lumbrical position. The results are good on both sides but there is intrinsic overaction of the middle finger which had the sublimis transfer.

arthritis, and the limitation of movement was due to articular changes rather than failure of the tendon graft. The fourth hand developed infection at the site of anastomosis, causing adhesions and limitation of extension of all fingers.

It should be emphasised, however, that the results would not have been so good if it were not for the painstaking work of the physiotherapists. The results in a few patients who left the district without staying for re-education were inferior. In such patients it would have been better to have done a sublimis transfer (Fig. 8).

In this study there has been an element of case selection which was not present in the series on sublimis transfers. In a number of patients with contractures before operation which would not respond to physiotherapy and splintage, a sublimis transfer was chosen, because we believed that it would result in a stronger corrective force. In the past three years about 15 per cent of all claw hands have had sublimis transfers, and most of these have imperfect results because they had stiff fingers. Had these patients with contractions been operated upon by the free grafting technique the proportion of excellent and good results might have fallen from 71 per cent to 62 per cent.

Most of these operations have been done by different trainees in hand surgery, and in every patient the final assessments have been made by a member of the team who took no part in the operation.

SUMMARY

1. Tendon grafts, in order to survive, have to develop a blood supply from their immediate environment. This causes adhesions.

2. Their final range of movement is therefore a sum of the length to which these vascular adhesions will stretch, and the range of movement of the normal tissues to which the tendon has become adherent.

3. Thus it is important that the tendon graft should lie in a bed of yielding material, and that no unyielding structures should be divided in the same wound. When possible, blunt tunnelling between short transverse incisions is the method of choice for placement of grafts.

4. The most crippling adhesions are those that grow from an imperfectly sutured cut end of tendon, leaving it unsatisfied. A new method of tendon anastomosis designed to prevent such adhesions is described.

5. A tendon grafting technique for intrinsic paralysis of the fingers in leprosy, using a radial extensor of the wrist as the motor and the plantaris tendon as the graft, is described.
6. A study of 861 fingers after the operation is presented.
7. The importance of re-education after operation is stressed.

I wish to thank my assistants and trainees for their meticulous care in record keeping which has made this study possible. I also wish to record my appreciation of the sterling work of our records clerk, Mr M. A. Furness. My thanks are due to CIBA for the production of a film demonstrating this grafting technique, now available in their film library. This study was assisted by a grant from the Indian Council of Medical Research. The tendon stripper and the tendon tunneller are made for us in India by the Indian Sterilizer Company, Madras 28, and in Britain by Messrs Chas. F. Thackray Ltd., Leeds 1.

REFERENCES

BRAND, P. W. (1950): The Orthopaedic Care of Leprosy Patients. *Journal of the Christian Medical Association, India*, **25**, 1.

BRAND, P. W. (1952): The Reconstruction of the Hand in Leprosy. (Hunterian Lecture.) *Annals of the Royal College of Surgeons of England*, **11**, 350.

BRAND, P. W. (1954): Hand Reconstruction in Leprosy. *In* British Surgical Practice. *Surgical Progress* 1954, p. 117. London: Butterworth & Co. (Publishers) Ltd.

BRAND, P. W. (1954): The Place of Physical Medicine and Orthopaedic Surgery in Leprosy. *Leprosy Review*, **25**, 5.

BRAND, P. W. (1955): The Value of Surgical and Physiotherapeutic Measures in Leprosy. *Leprosy in India*, **27**, 131.

BRAND, P. W. (1956): Treatment of Leprosy. II. The Role of Surgery. *New England Journal of Medicine*, **254**, 64.

BRAND, P. W. (1958): Paralytic Claw Hand. *Journal of Bone and Joint Surgery*, **40–B**, 618.

BRAND, P. W. (1959): Deformity in Leprosy. Orthopaedic Principles and Practical Methods of Relief. In *Leprosy in Theory and Practice*, p. 265. Edited by R. G. Cochrane. Bristol: John Wright & Sons Ltd.

BUNNELL, S. (1932): Contractures of the Hand from Infections and Injuries. *Journal of Bone and Joint Surgery*, **14**, 27.

BUNNELL, S. (1942): Surgery of the Intrinsic Muscles of the Hand Other Than Those Producing Opposition of the Thumb. *Journal of Bone and Joint Surgery*, **24**, 1.

BUNNELL, S. (1956): *Surgery of the Hand.* Third edition. Philadelphia: J. B. Lippincott Company.

DEHIO, K. (1897): Ueber die Lepra anaesthetica und den pathogenetischen Zusammenhang ihrer Krankheitserscheinungen. *Mittheilungen und Verhandlungen der internationalen wissenschaftlichen Lepra—Conferenz zu Berlin im October* 1897. Band 2, p. 85. Berlin: August Hirschwald.

EYLER, D. L., and MARKEE, J. E. (1954): The Anatomy and Function of the Intrinsic Musculature of the Fingers. *Journal of Bone and Joint Surgery*, **36–A**, 1.

FOWLER, S. B. (1949): Extensor Apparatus of the Digits. *Journal of Bone and Joint Surgery*, **31–B**, 477.

GLISSAN, D. J. (1932): The Use of the Plantaris Tendon in Certain Types of Plastic Surgery. *Australian and New Zealand Journal of Surgery*, **2**, 64.

GOLDNER, J. L. (1953): Deformities of the Hand Incidental to Pathological Changes of the Extensor and Intrinsic Muscle Mechanisms. *Journal of Bone and Joint Surgery*, **35–A**, 115.

HARRIS, C., Jun., and RIORDAN, D. C. (1954): Intrinsic Contracture in the Hand and its Surgical Treatment. *Journal of Bone and Joint Surgery*, **36–A**, 10.

KAPLAN, E. B. (1953): *Functional and Surgical Anatomy of the Hand.* Philadelphia: J. B. Lippincott Company.

LITTLER, J. W. (1949): Tendon Transfers and Arthrodeses in Combined Median and Ulnar Nerve Paralysis. *Journal of Bone and Joint Surgery*, **31–A**, 225.

MASON, M. L., and SHEARON, C. G. (1932): The Process of Tendon Repair; an Experimental Study of Tendon Suture and Tendon Graft. *Archives of Surgery*, **25**, 615.

MAYER, L. (1916): The Physiological Method of Tendon Transplantation. *Surgery, Gynecology and Obstetrics*, **22**, 182.

NEY, K. W. (1921): A Tendon Transplant for Intrinsic Hand Muscle Paralysis. *Surgery, Gynecology and Obstetrics*, **33**, 342.

PILCHER, R. (1939): Repair of Hernia with Plantaris Tendon Graft. *Archives of Surgery*, **38**, 16.

PULVERTAFT, R. G. (1956): Tendon Grafts for Flexor Tendon Injuries in the Fingers and Thumb. A Study of Technique and Results. *Journal of Bone and Joint Surgery*, **38–B**, 175.

RIORDAN, D. C. (1954): Tendon Transplantations in Median-Nerve and Ulnar-Nerve Paralysis. *Journal of Bone and Joint Surgery*, **35–A**, 312.

STILES, Sir H. J., and FORRESTER-BROWN, M. F. (1922): *Treatment of Injuries of the Peripheral Spinal Nerves*, p. 180. London: Henry Frowde and Hodder & Stoughton.

SIMPLICITY OF APPROACH TO TREATMENT OF THE INJURED HAND

P. S. LONDON, BIRMINGHAM, ENGLAND

From the Birmingham Accident Hospital

With the increasing interest taken in the surgery of the hand there have been striking advances in technique, materials and the standard of results obtained. The literature abounds with accounts of ingenious, elaborate and successful methods of treatment, especially treatment designed to reconstruct the naturally deformed or the mutilated hand. Clearly such successes have not been achieved without disappointments, and even disasters, but these have gone for the most part unremarked. There is in consequence considerable incentive to think of the mutilated hand as being in need of reconstruction and of saving injured parts with a view to later structural restoration by means of grafts and transplants of various kinds. The successes are published, the failures are regretted in private; the incentive is undiminished.

Against this background of technical virtuosity it may seem presumptuous to advocate a simple approach to treating injured hands but it offers ample opportunity for the surgeon who is interested rather than specially skilled in the subject to achieve satisfactory results in terms of function. The essence of manual skill is to feel and to grasp. For this purpose the

FIG. 1

FIG. 2

The patient, a man of sixty-seven, made good use of this extremity. A fracture of the little finger was used to rotate it towards the stump of the thumb.

minimum requirement is skin with normal or nearly normal sensibility and at least two digits that can be brought firmly together and separated. Such a remnant is ungainly but it is useful and could not be made more useful by any addition to its structure (Figs. 1 and 2).

Moberg (1958) has stressed the importance of tactile gnosis—the ability to distinguish size, texture, consistency, shape and temperature by touch alone. Tactile gnosis is not to be expected in any graft that has been separated from its normal nerve supply. Many grafts will in time regain enough sensibility to protect against harmful influences. Testing with pin, wool or von Frey's hairs may suggest that reinnervation has proceeded to a gratifying extent but sensibility may still be well below the standard of tactile gnosis. When sensibility is

FIG. 3

This flap had been in place for twelve years but was uncomfortable, awkward and almost insensitive. The hand was well used, however, because the fingers were healthy.

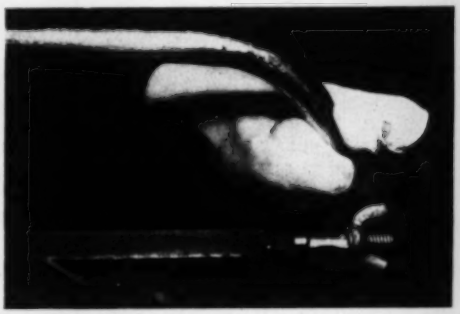


FIG. 4

FIG. 5

FIG. 6

FIGS. 4 TO 6

An opposition post formed from bone grafts and skin. Although in use the opposition post bears a dressing. This one healed and remained so—not all do. The radiograph shown in Figure 6 was taken in April 1960, many years after the repair. (*By courtesy of Mr Mervyn Evans.*) Figure 4 is reproduced by kind permission of the Editor, *British Journal of Plastic Surgery.*

tested by the patient's ability to manipulate small objects with the eyes closed the aptness of Moberg's concept of a blind or a sighted digit is strikingly demonstrated.

This at once calls in question the desirability of replacing skin on the most usefully perceptive parts of the hand by flaps and tubes bereft of their normal innervation and consequently blind or purblind. One or two fingers stripped of skin are often better amputated, but a thumb covered by abdominal skin may be a small handicap provided other digits possess

FIG. 7

FIG. 8

FIG. 9

FIGS. 7 TO 9

With careful trimming and closure useful stumps were preserved and retained tactile gnosis. (Reproduced from *Modern Trends in Accident Surgery and Medicine*, by permission of Messrs Butterworth & Co. (Publishers) Ltd.)

enough tactile gnosis to compensate for the insensitiveness of the thumb (Fig. 3). An insensitive reconstruction that is also rigid is usually less successful in practice. Though it may be of creditable appearance, its inherent defects make it vulnerable and much more liable to ulceration than capable of healing. With nothing more than part of the thumb and a mere stump of carpus it may be worth fashioning an opposition post from grafts of skin and bone (Figs. 4 to 6), but it may turn out to be of small value. A thumb and a palm is not usually

worth adding to surgically but even short sensitive stumps of fingers should be preserved (Figs. 7 to 9).

FIG. 10

FIG. 11

FIG. 12

FIGS. 10 TO 12

The little and ring fingers were not worth saving. The hand healed after one operation and the remaining digits regained almost full strength and range of movement.

In many instances the patient will be best served by simple surgical toilet and careful repair of the remaining structures that can reasonably be expected to be useful (Figs. 10 to 16).

When the viability of important structures is in doubt they are often better retained in the first instance even though they may later have to be discarded (Figs. 17 to 19).

In other cases it is possible to maintain or restore tactile gnosis by using innervated skin from other parts of the hand and particularly from fingers that have been badly damaged.

FIG. 13

FIG. 14 FIG. 15 FIG. 16

Damage to tendons, skin and bone. No skin lost. Repair by suture of injured structures. Final function good in general though diminished in detail.

Though they may be amenable to reconstruction the process will be lengthy and may leave the patient with a finger that is useless and a handicap because of stiffness and insensibility (Figs. 11 and 12 and 20 to 29). The fact that a flap with a neurovascular pedicle may later

have that pedicle cut through does not lessen the simplicity of the method and it may not significantly impair tactile gnosis (Figs. 30 to 32). From the patient's point of view it is advantageous to be spared the experience of having the hand sewn temporarily to some other part of the body.

FIG. 17

FIG. 18

FIG. 19

Immediate amputation of index and long fingers and part of thumb. Ring finger subsequently died and after part of the metacarpus was removed a useful claw remained.

When tactile gnosis remains on reparable digits it is justifiable to go to considerable lengths to retain them. An initial simple procedure may not suffice and a more elaborate programme then becomes necessary (Figs. 33 to 36).

FIG. 20

FIG. 21

FIG. 23

FIG. 22

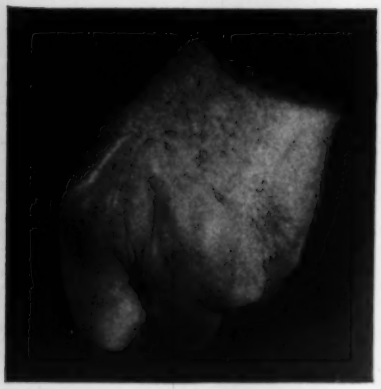


FIG. 24

Penetrating wound of the hand. Skin of long finger, which was technically reparable, used instead to fill defect with little impairment of eventual function. (Figures 20 to 22 are reproduced by kind permission of the Editor, *British Journal of Plastic Surgery*.)

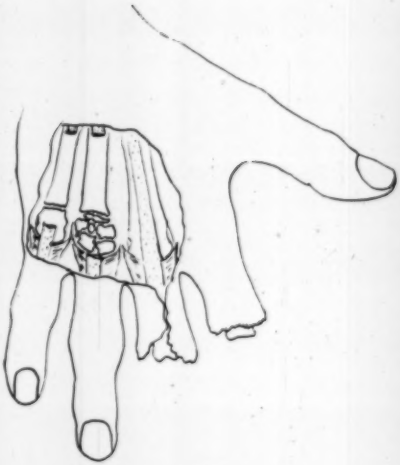


FIG. 25

FIG. 26

FIG. 27

FIG. 28

Ring finger sacrificed to allow large defect to be made good by skin from the hand. Given the prospect of healing by first intention, the extensor tendon to the long finger was transplanted to the little finger and the fracture of the fifth metacarpal was fixed. Using the hand gainfully within one month of injury. (Reproduced from *Modern Trends in Accident Surgery and Medicine*, by permission of Messrs Butterworth & Co. (Publishers) Ltd.)

FIG. 29

A strip of skin with normal neurovascular supply was taken from the badly damaged middle finger to complete the index finger, which had lost skin from one side.

FIG. 30

FIG. 31

FIG. 32

FIGS. 30 TO 32

Stump of index finger split into three flaps which were used to complete the thumb and long finger. The third flap was used to clothe the raw surfaces leaving only a small area to be covered by split skin.

FIG. 33

FIG. 34

FIG. 35

FIG. 36

The hand was crushed between rollers and the skin stripped from part of the palm and the bases of the fingers. It was stitched back under local anaesthesia but most of it died. The remaining living tissue included skin on the tips of the fingers, each with a neurovascular pedicle. Free skin grafting failed only on the bare bone of the phalanges. An abdominal flap was applied. The fingers were then too stiff and bent to be useful but were straightened by corrective arthrodesis. The hammer shown weighed 4 pounds.

DISCUSSION

The approach advocated here is based upon the universal principle of treating wounds: to bring healthy, living tissues together and to keep them there until healed. This necessarily entails the sacrifice of dead and damaged tissue and the provision (by grafting) of a second healthy surface when one surface of the wound has been destroyed. The rest that assists healing may be best ensured by internal fixation of fractures.

In favourable cases, once the wound has healed successfully the remnant of the hand is ready for use; in others more surgery is required, but it is not unusual to find that secondary operations could have been included advantageously in the first. This saves much time, avoids many of the physical troubles of prolonged disuse, and may make physiotherapy entirely unnecessary. Apart from this there are considerable psychological advantages. The patient does not have time to develop a fixed mental image of a disabled extremity. Any initial enthusiasm to get back to work is liable to be sapped by prolonged idleness and may suffer further from the persuasions of others that too early a return to work may weaken a claim for compensation. Much can be done to mitigate these troubles by the earliest possible meeting of the patient and the surgeon who is going to look after his hand. It may not at first be possible to make an accurate or detailed forecast of the treatment required and the result to be expected, but the patient can at least be given reason to have confidence in his surgeon; this should be reinforced by further discussion as the outcome becomes confidently discernible.

The initial operation is crucial; it must be designed with the patient's needs and the prospects of useful survival of the injured structures clearly in mind. It must take account of the possible need for reconstruction and must lay the foundations for whatever may be required. On the other hand, it must not in any way jeopardise the survival of useful remaining structures and it must be followed by prompt healing. The urge to conserve may have to be restrained lest it burden nimble parts with others that are stiff and numb, or hazard them by infection spreading from a part that had been better discarded. That brilliant operations exist and may be feasible in a given case is not in itself the slightest justification for their performance. Much will depend upon the patient's needs and upon his ability. The intelligent person may overcome successfully grave shortcomings of feeling and movement; the simple or careless may not be trusted to keep even a small flap intact, let alone use it.

SUMMARY

1. The success of any method of treating the injured hand is to be measured by the use that is made of the remnant.
2. Careful, prompt surgical treatment of the wound will usually allow prompt healing.
3. Skin-grafts, internal fixation of fractures and the eking out and rearrangement of tissues that have escaped injury have an important place in primary treatment.
4. Many hands so treated are ready for use after one operation and within a few weeks of being injured.
5. Reconstruction in several stages should not be carried out unless it offers a reasonable prospect of improvement that will be useful to the particular patient.

REFERENCE

MOBERG, E. (1958): Objective Methods for Determining the Functional Value of Sensibility in the Hand. *Journal of Bone and Joint Surgery*, **40–B, 454.**

CAUSES OF FAILURE AFTER REPAIR OF THE MEDIAN NERVE

I. G. MACKENZIE, ABERDEEN, SCOTLAND, and C. G. WOODS, LEEDS, ENGLAND

From the Institute of Orthopaedics and Royal National Orthopaedic Hospital, London and Stanmore

In a recent review of the results of repair of the median nerve at the wrist we found that almost half were unsatisfactory. The present study was undertaken in order to find out the causes of failure, and to explore the possibilities of improving the results.

MATERIAL

The patients were operated upon at the Royal National Orthopaedic Hospital between January 1948 and December 1955. This gave a follow-up period of at least three years. There were forty patients in whom histological preparations of the resected nerve ends were available for study. Ten patients operated upon during the same period were excluded because histological preparations were not available.

METHODS OF EXAMINATION

Clinical—The results were analysed by the method recommended in *Peripheral Nerve Injuries*, the report by the Nerve Injuries Committee of the Medical Research Council (1954). This method was used by Nicholson and Seddon (1957) in their analysis of nerve repair in civil practice and we used their criteria of useful recovery to divide the cases into clinical failures and successes.

TABLE I

ANALYSIS OF POSSIBLE CAUSES OF FAILURE

Factors influencing result	Number of cases
Level of lesion	—
Gap after resection	—
Extent of mobilisation	—(See Fig. 1)
Delay before repair	2
Separation of suture line	2
Unequal stump diameter	1
Incongruity of funicular pattern	—
Inadequate resection (distal)	4
Endoneurial fibrosis	4
Unexplained failures	5
Total	18

A useful degree of sensory recovery was defined as recovery of pain and touch sensibility throughout the autonomous area even if over-reaction to stimuli was present (Grade 2+). A useful degree of motor recovery was taken to be that in which the thenar muscles contracted against gravity (Grade 3).

Histological—Cross-sections of the nerve were made at the proximal and distal levels of resection: these were stained by the lissamine-fast-red tartrazine modification of the Masson trichrome technique (L.F.R.) (Lendrum 1947) and were examined to assess the amount of endoneurial fibrosis. This assessment was made by examination of the sections in the usual way and by a further examination with the sections between crossed polaroid sheets.

ANALYSIS OF RESULTS

Of the forty patients twenty-two had useful recovery and in eighteen the operations were regarded as failures.

POSSIBLE CAUSES OF FAILURE

The factors responsible for failure have been discussed by Seddon (1949). Those thought to be responsible in this series are shown in Table I.

Level of lesion—The level of the lesion is important but it was not relevant in this series, in which all the lesions were at the level of the wrist.

Gap—The gap that remains after resection of the nerve ends is also important and can prejudice recovery if it is greater than seven centimetres (Zachary 1954a). There was no gap of such an extent in this series.

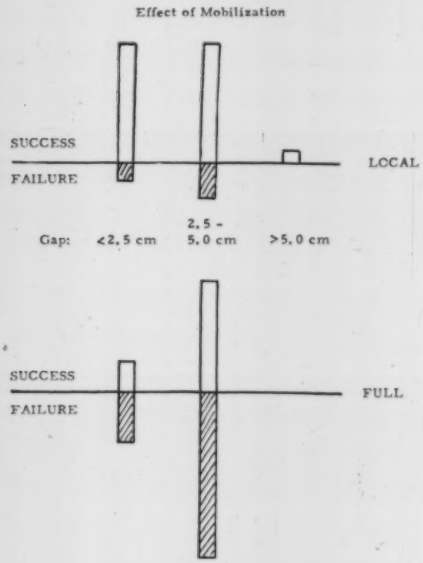


FIG. 1
Effect of mobilisation on results.

Extent of mobilisation—Nicholson and Seddon (1957) have shown that local mobilisation of the nerve and flexion of both elbow and wrist gives a higher proportion of good results than full mobilisation to the elbow which allows suture to be carried out with the elbow flexed and the wrist neutral. A possible reason for this is that extensive mobilisation interferes with the blood supply of the nerve. Their conclusion is borne out by this series (Fig. 1).

Interval between injury and repair—The longest interval between injury and operation following which useful recovery may be expected in this type of case is said to be thirty-two months (Zachary 1954*b*). Two patients in this series were operated upon after longer intervals, and in both the operation was a clinical failure. In each of these cases, however, the resection of the distal stump was not clear of glioma. In this series the longest interval followed by a satisfactory result was fifteen months.

Post-operative separation of the suture line—Two patients who did not make the anticipated recovery agreed to re-exploration about nine months later and were found to have large neuromata at the site of the previous suture, possibly indicating that separation had occurred. Such separation can be detected if radio-opaque markers are attached to the nerve sheath near the suture line (Fig. 2) and observed radiographically. Too rapid extension of the elbow and wrist after the operation is a possible cause of rupture at the suture line. However, the rate of extension was no greater in the cases of failure than in patients with successful results.

Condition of the nerve stumps—The gross condition of the nerve stumps is also important. In one failure the diameter of the distal stump was noted at operation to be much smaller than that of the proximal stump.

Other factors—Incongruity of the funicular pattern is a cause of failure in proximal lesions, and one over which the surgeon has no control (Sunderland 1945). At the level of the wrist, however, motor and sensory divisions of the nerve are well defined.

In every case the level of resection was judged to be adequate at the time of operation. That is, there was no palpable thickening of the nerve, the epineurium was mobile, and there appeared to be intact nerve bundles at both proximal and distal levels of resection. In eight cases this clinical judgment was not supported by the histological findings. In three cases the proximal level of resection had passed through neuromatous tissue. In two of these the clinical result was satisfactory, and in the remaining case, which was a failure, the distal section was through glioma. In three other cases the distal section passed entirely through glioma and these were clinical failures. It appears that the presence of neuromatous tissue in the proximal stump does not preclude useful recovery, but that the presence of gliomatous tissue in the distal stump is more sinister.

FIG. 2
Radiograph showing radio-opaque markers.

The degree of fibrosis of the endoneurium can also be a limiting factor in recovery after suture (Holmes and Young 1942). All degrees of increase in the endoneurial collagen were seen up to a stage where it was as thick inside the nerve bundle as around it (Figs. 3 to 6). There was, of course, variation between individual nerve bundles in any given case although they usually showed the same degree of fibrosis. In all cases empty Schwann tubes were found in the distal nerve bundles, although they were smaller and less numerous in those bundles showing the most fibrosis. In four cases there were bundles of collagen in the endoneurium as thick as those in the epineurium (Fig. 6) (three in the distal end only, and one in both proximal and distal ends). All the four patients had poor clinical results and it is suggested that this degree of collagenisation may have affected the result.

DISCUSSION

Two major points have emerged from this study. The first concerns the use of radio-opaque markers. In two cases in which re-exploration was agreed to, the finding of a large neuroma suggested that the suture line might have parted. If radio-opaque markers had been used this could have been determined at an early stage, and re-exploration carried out immediately. Separation of the suture line may have been the critical factor in the five unexplained failures in this series. The use of markers adds little time to the operation and removes doubts about failure from this cause.

The second point concerns the adequacy of resection of the nerve ends. In four patients with a poor result the distal face was found to be composed of gliomatous tissue, and in four other cases of clinical failure there was considerable endoneurial collagenisation. The evidence that we have indicates that endoneurial fibrosis up to the degree depicted in Figure 5 is compatible with a satisfactory clinical result, and the aim should be to resect the end-bulbs so that this, or a more favourable result, is achieved.

Provided that the final gap does not exceed seven centimetres the nerve ends may be resected repeatedly until the best condition is achieved. Since the degree of endoneurial fibrosis often decreases considerably over quite short distances, especially in the distal stump (Figs. 7 and 8), there is considerable encouragement to perform " trial sections." Histological control of this procedure would be required and this means the preparation and examination of frozen sections.

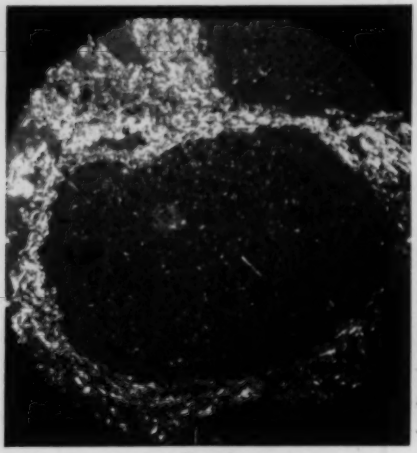


FIG. 3

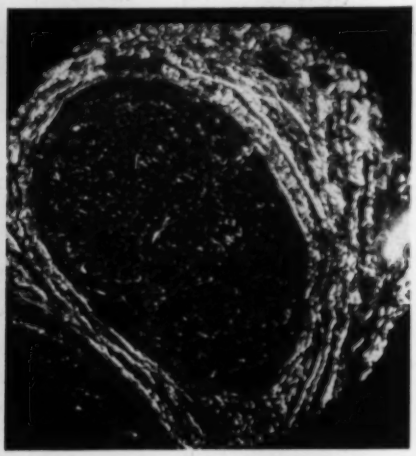


FIG. 4

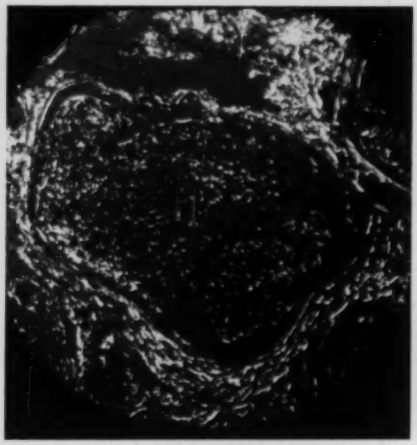


FIG. 5

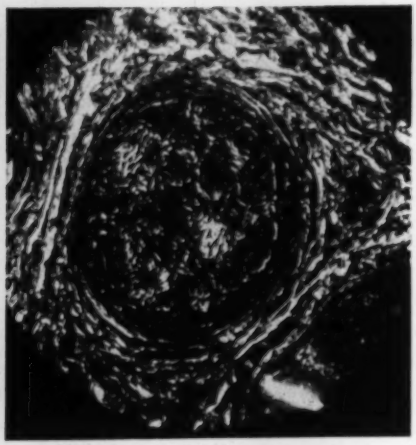


FIG. 6

Examples of the degree of fibrosis found in nerve bundles in this series of cases, from the minimal increase depicted in Figure 3 to the condition in Figure 6 where condensation of collagen in the endoneurium has produced birefringent bundles as thick as those found in the surrounding connective tissue. (Paraffin sections Lissamine-fast red. Polarised light, × 100.)

The material from a few patients has been examined as frozen sections, both as unstained preparations examined between crossed polaroid sheets and after staining with L.F.R. Provided that no fat solvents make contact with the unstained section, both the degree of fibrosis and the density and size of myelin sheaths may be assessed in such sections, which can be prepared in a few minutes (Figs. 9 and 10). These sections have been preserved in water mountant

and do not appear to have deteriorated. The stained preparations, although different in some respects from paraffin-embedded material, give as much information and appear to be as permanent as paraffin sections (Figs. 11 to 14). We hope, therefore, to give this technique a

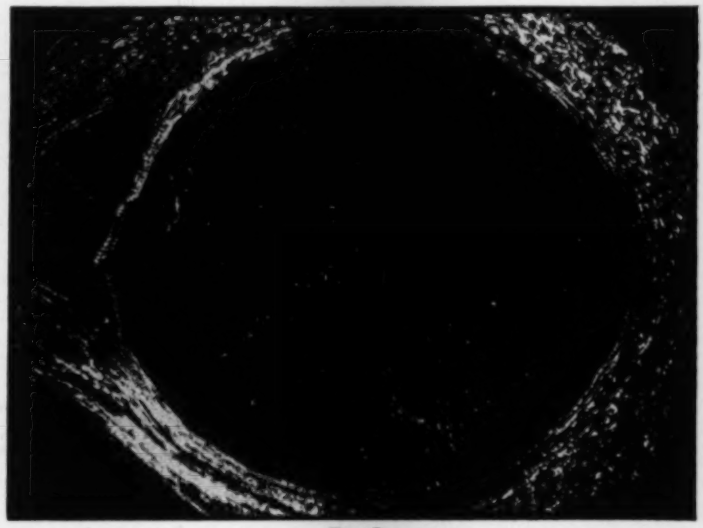


FIG. 7

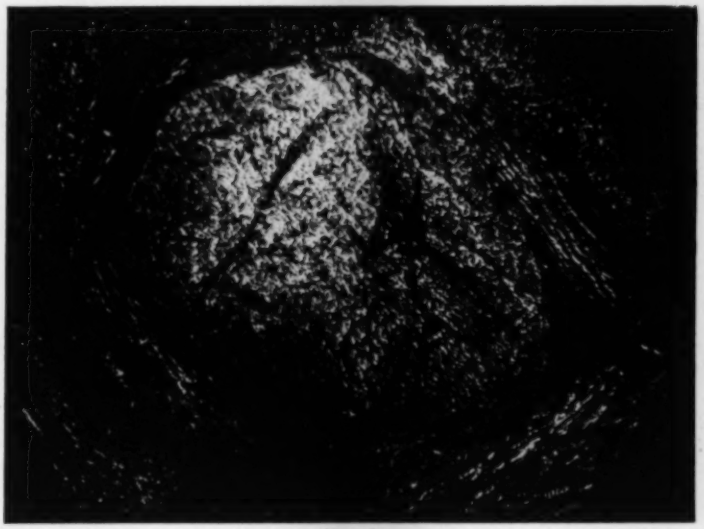


FIG. 8

Sections taken from a distal end-bulb. Figure 7 is at the final level of resection. Figure 8 is from a section which was 0·5 centimetre proximal to the final level of resection. The difference in degree of fibrosis of the endoneurium is striking. (Paraffin sections Lissamine-fast red. Polarised light, × 140.)

fuller trial, although Blackwood and Holmes (1954) concluded that the disadvantages attached to the use of frozen sections outweigh their usefulness as applied to the particular problem of nerve repair.

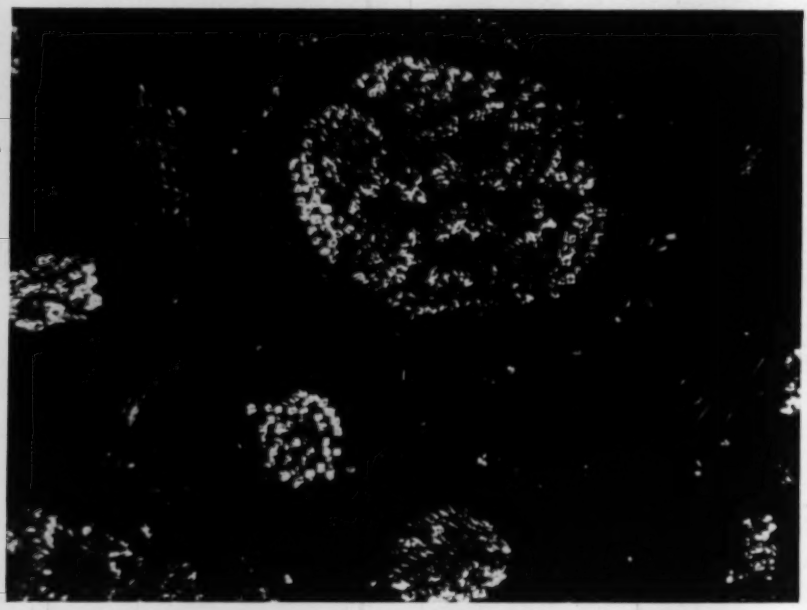


FIG. 9

One large and two smaller bundles of nerve fibres occupy the centre of the photomicrograph. The brightly birefringent circles, some of which have a "hot cross bun" appearance, are myelin sheaths. (Frozen section, unstained in water: proximal stump. Polarised light, ×80.)

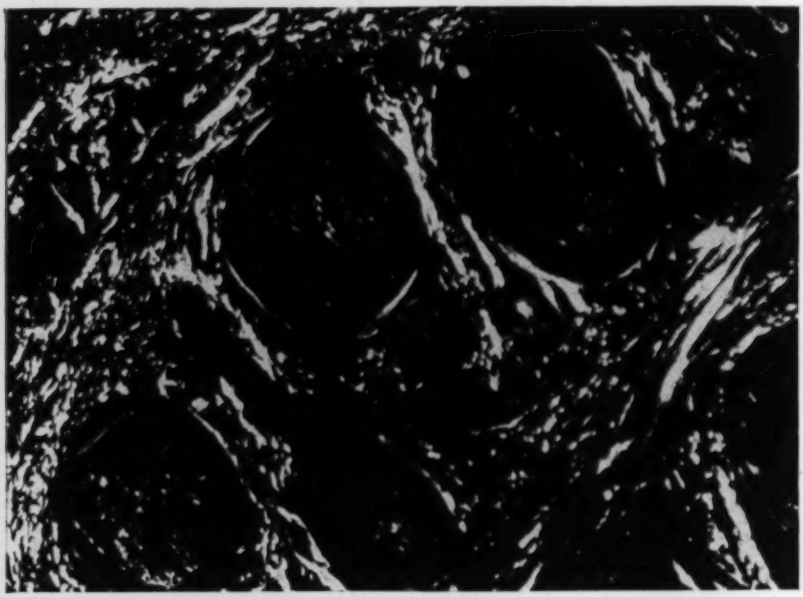


FIG. 10

The nerve bundles do not contain any large myelinated fibres. There is an increase in the collagenisation of the neurium. (Frozen section, unstained in water: distal stump. Polarised light, ×80.)

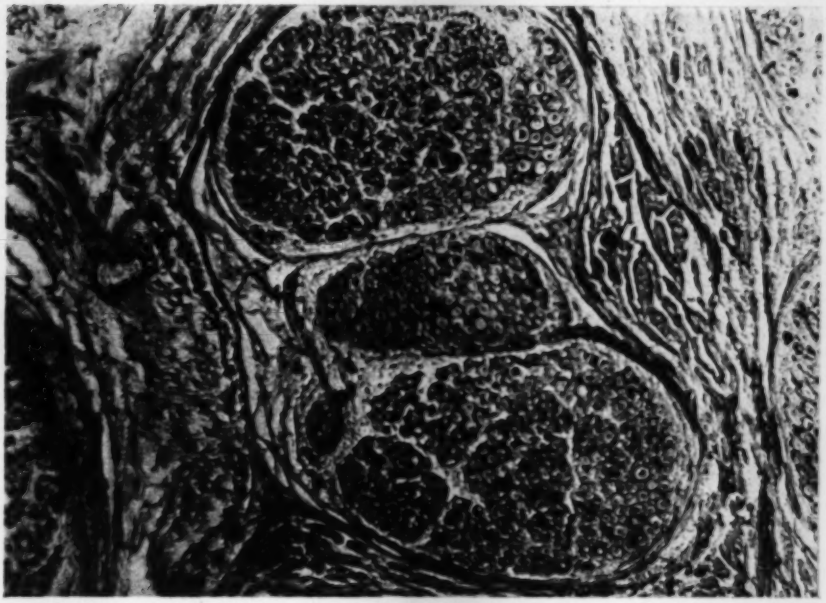


FIG. 11

The striking feature of peripheral nerve frozen sections is the larger size of the myelinated sheaths as compared with similar material embedded in paraffin. (Proximal level of resection. Frozen section Lissamine-fast red, × 80.)

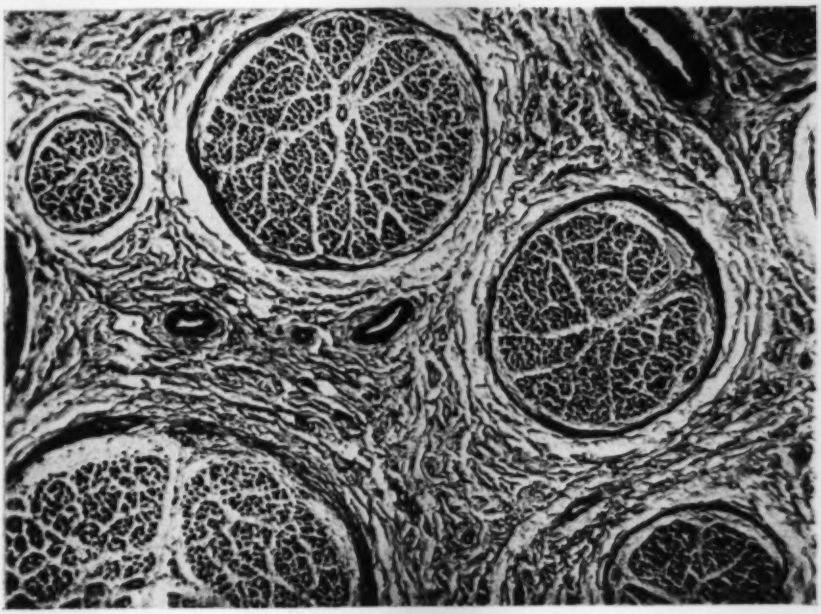


FIG. 12

Proximal level of resection. A " conventional " section for comparison with Figure 11. (Paraffin section Lissamine-fast red, × 80.)

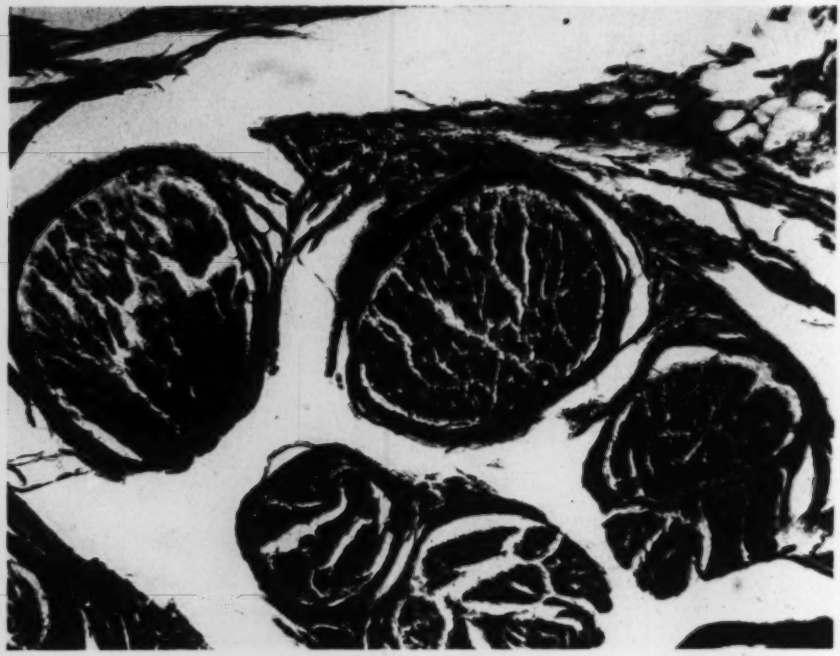


FIG. 13

Distal level of resection. One of the disadvantages of unembedded sections, the tendency for the section to break up, is obvious. This section gives essential information about adequacy of resection: it is clear of glioma and not severely collagenised. (Frozen section Lissamine-fast red, ×80.)

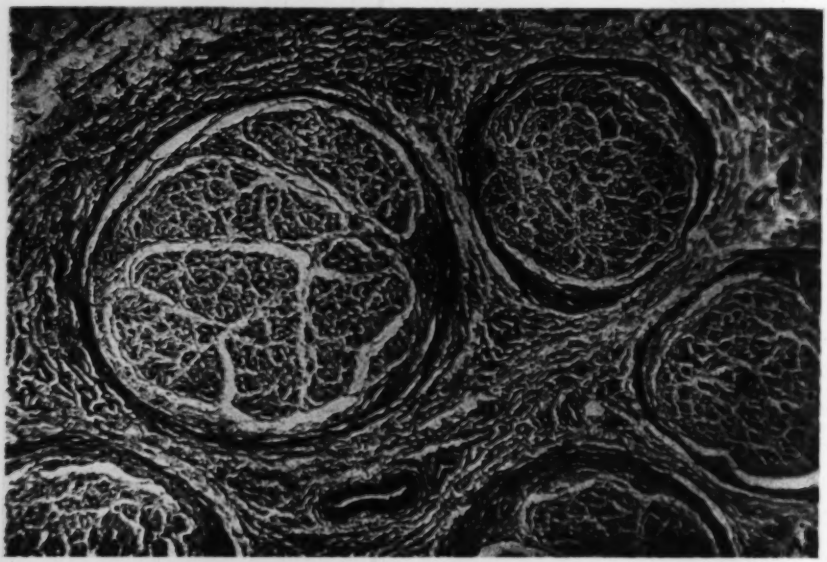


FIG. 14

Distal level of resection. A "conventional" histological section for comparison with Figure 13. Although this section is aesthetically more pleasing it does not provide any information that cannot be found in a stained frozen section. (Paraffin section Lissamine-fast red, ×80.)

SUMMARY

1. The clinical results in forty cases of repair of the median nerve at the wrist have been examined. Almost half were unsatisfactory.
2. The factors that may have predisposed to failure of adequate re-innervation are discussed.
3. The results might be improved by the use of radio-opaque markers for early detection of separation at the suture line, and by the use of frozen sections to determine the adequacy of resection.

We wish to express our thanks to Mr H. J. Seddon and to Dr H. A. Sissons for their encouragement and advice during this study. Our thanks are due to Miss M. Tomlinson and Mr R. Whitley for technical and photographic assistance respectively.

REFERENCES

BLACKWOOD, W., and HOLMES, W. (1954): Histopathology of Nerve Injuries. *In* Peripheral Nerve Injuries. *Medical Research Council Special Report No.* 282, p. 110. Edited by H. J. Seddon. London: Her Majesty's Stationery Office.

HOLMES, W., and YOUNG, J. Z. (1942): Nerve Regeneration After Immediate and Delayed Suture. *Journal of Anatomy*, **77**, 63.

LENDRUM, A. C. (1947): Routine Diagnostic Technique. In *Recent Advances in Clinical Pathology*, p. 451. Edited by S. C. Dyke. London: J. & A. Churchill Ltd.

NICHOLSON, O. R., and SEDDON, H. J. (1957): Nerve Repair in Civil Practice. *British Medical Journal*, **ii**, 1,065.

SEDDON, H. J. (1949): The Practical Value of Peripheral Nerve Repair. *Proceedings of the Royal Society of Medicine* (Section of Orthopaedics), **42**, 427.

SUNDERLAND, S. (1945): The Intraneural Topography of the Radial, Median and Ulnar Nerves. *Brain*, **68**, 243.

ZACHARY, R. B. (1954*a*): Results of Nerve Suture. *In* Peripheral Nerve Injuries. *Medical Research Council Special Report No.* 282, Table 108, p. 388. Edited by H. J. Seddon. London: Her Majesty's Stationery Office.

ZACHARY, R. B. (1954*b*): Results of Nerve Suture. *In* Peripheral Nerve Injuries. *Medical Research Council Special Report No.* 282, Table 99, p. 383. Edited by H. J. Seddon. London: Her Majesty's Stationery Office.

RESTORATION OF SENSIBILITY IN THE HAND BY NEUROVASCULAR SKIN ISLAND TRANSFER*

R. TUBIANA and J. DUPARC, PARIS, FRANCE

From the Clinique Orthopédique et Réparatrice de l'Hôpital Cochin†, and the Centre de Traumatologie de l'Hôpital Saint-Louis‡

The recent development of peripheral nerve surgery owes much to the work of Seddon; in the hand, Moberg (1958) has pointed out the importance of tactile gnosis.

Experience has shown that prehension is useful only in the presence of cutaneous sensibility; it is therefore necessary to re-establish sensibility of the hand whenever possible. If it is impossible to undertake direct repair of the nerves, another procedure must be considered.

Since 1958 we have used in ten patients a sensitive " hetero-digital " cutaneous transplant with its neurovascular pedicle. This procedure was suggested by Moberg (1955) and has been carried out by Littler (1960) and probably by other surgeons.

TECHNIQUE

The cutaneous transplant—The digital skin island transfer used corresponds to the terminal zone of distribution of the palmar collateral neurovascular pedicle. It is cut oval in shape, takes in half of the pulp and extends upwards onto the middle segment of the finger if necessary.

FIG. 1

The relative value of sensibility in various sites. In black, the areas where sensibility is essential; cross-hatched, the areas where loss of sensibility is least inconvenient.

The donor finger—There must be two conditions present for the choice of the donor finger. The flap must have perfect innervation and blood supply, and removal of the island must give rise to minimal disturbance.

In fact, sensibility does not have the same value in all the fingers (Fig. 1). Sensibility is essential on the palmar aspect of the thumb, on the lateral aspect of the fingers opposing the thumb, and on the medial aspect of the little finger.

On the other hand, loss of sensibility usually gives less disturbance on the medial aspects of the middle and ring fingers, for which reason they constitute the donor areas that we use most. As an alternative, when these sites are not available, it is possible to use the lateral aspects of the ring and little fingers or even the medial aspect of the index.

The approach—A combined digital and palmar incision exposes the entire pedicle. This incision is midlateral in the finger and curved in the palm (Fig. 2).

Liberation of the pedicle requires division between two ligatures of the collateral artery of the neighbouring finger, and cleavage proximally of the digital nerve in the palm (Fig. 3).

* Paper read at the Meeting of the British Orthopaedic Association in Glasgow on April 7, 1960.

† Service of Professor Merle d'Aubigné. ‡ Service of Professor J. Cauchoix.

FIG. 2

FIG. 3

FIG. 4

FIG. 5

FIG. 6

FIG. 7

FIGS. 2 TO 7

Transfer of sensitive skin to pulp of a thumb rendered insensitive by damage eight years previously to the digital nerves at the base of the thumb. Figure 2—Showing the incision for island transfer from the medial side of the middle finger to the thumb. Figure 3—Ligature and division of the artery to the ring finger. Figure 4—The cutaneous transplant with its pedicle completely freed. Figure 5—The skin of the pulp of the thumb is used as a graft to cover the donor area on the long finger. Figure 6—The transplant is placed at the level of the pulp of the thumb. Figure 7—The appearance of the hand three months after the operation. The whole of the thumb has recovered sensation.

The dissection of the pedicle is carried to the base of the island which is taken with all its subcutaneous tissue.

While the pedicle is being freed (Fig. 4) it is important to take particular care of the small vessels which arise from it; they are carefully ligated. An anomaly of the arterial distribution may give rise to difficulties. In one patient the digital artery to the fourth cleft arose from the deep, not the superficial arch, and resulted in shortening of the pedicle. This abnormality did not make the transfer of the flap impossible; the difficulty was overcome by flexing both fingers during the post-operative period. Full extension was regained within two months.

After this dissection the tourniquet is released to prove the viability of the island.

Transfer of the island—An area of skin of the same dimensions as the cutaneous island transfer is excised from the finger where the sensibility is to be restored. This excised skin may be used to cover the donor site (Fig. 5). The sensitive cutaneous transplant can be brought through a continuous incision or by tunnelling to the site where it will be implanted (Figs. 6 and 7). It is important to avoid any damage to the pedicle by torsion, excessive tension or compression. A dressing immobilises the fingers for a few days in the most favourable position for the survival of the transplant.

RESULTS

We shall discuss the restoration of sensibility and of function.

Sensibility—The expected results have been obtained in the ten patients in whom we have practised this operation: the hetero-digital cutaneous transplant has conserved its viability and sensibility, but we have also noticed alterations in sensibility which are of interest.

In the cutaneous transplant—In all the patients, sensibility in the skin island transfer is comparable in quality to the normal. Two-point discrimination is at first a little disturbed, but later becomes almost normal.

In six of ten patients the sensibility perceived by the patients has evolved in a functional and progressive adaptation.

Immediately after the operation the patient appreciates stimuli as if coming from the donor site. After a variable length of time, usually a few weeks, the sensibility of the receiving finger is added to the sensibility of the donor finger. The perception of this " double sensibility " modifies itself progressively and the patient becomes more and more aware of his receiving finger. In agreement with Moberg, it seems useful to distinguish between academic recovery and functional recovery after any operation for the restoration of sensibility. If, perhaps, the sensation between the giving and receiving fingers is confused during the neurological examination, mistakes of perception are not usually made from the functional point of view. However, the passing from one stage to another in the evolution is not constant, and delays, which are very variable, seem to be influenced by the patient's psychological condition and the restoration of the use of the finger.

In four cases, even after many months, the sensibility of the receiving finger is still felt as of the donor finger. It is interesting to note that in all these four patients the finger operated upon was, for various reasons, rarely used.

Around the transplant—We have noticed the presence of a progressive sensibility which spreads from the cutaneous transplant at varying rates. It is noticeable that this new sensibility is usually immediately localised to the receiving finger. The quality of this sensibility is not as good as in the island, but it is protective.

Many explanations can be offered for this spread of sensibility. It seems that it comes from the transplanted nerve; the abundant terminal branching of the digital nerve may explain this high potential of diffusion. The penetration into the neighbouring tissues is more rapid when it is not limited by sclerosis, and probably explains the individual differences; but we have often noticed that the perception in the cutaneous transplant and perception

FIG. 8

FIG. 9

FIG. 10

FIGS. 8 TO 10

Section of the median nerve at the wrist eight years earlier. Transfer of a cutaneous transplant taken from the medial side of the ring finger and inserted on the lateral side of the index. Figure 8—The incision. Figure 9—The cutaneous transplant with its pedicle entirely freed. Figure 10—The appearance of the hand four months after operation. The whole index finger has recovered sensation.

FIG. 11

FIG. 12

FIG. 13

FIG. 14

Reconstruction of thumb after traumatic amputation of index finger and thumb. Figure 11—Condition before operation. Figure 12—Reconstruction of the thumb by a tube pedicle raised from the opposite forearm, insertion of a bone graft from the ilium and skin island transfer from the medial side of the ring finger. Figures 13 and 14—Six months after operation, all the tissues of the reconstructed thumb have recovered sensibility, including those of the tubes. Pinch and grasp are possible.

around it are different, since the peripheral sensibility is at first, in most cases, that of the receiving finger; it is impossible at present to explain this difference in localisation.

These discussions which interest neurologists to whom we have shown these patients must not allow us to forget the functional side of this operation.

The functional results—These depend on several considerations.

The quality of perception—Function is really good only when the patient is adapted to this new perception. This adaptation takes, as we have seen, a variable time. The extension of sensibility around the flap improves the functional result considerably.

The nutrition—The transfer of such a neurovascular cutaneous transplant improves considerably the nutrition of the injured finger. This procedure gives not only sensibility but also an important vascular supply. We have noted in every case a marked increase in the suppleness of the tissues and sometimes of the joints of the recipient finger.

Pain—In two patients with anaesthetic and painful hands we had hoped that re-establishing the sensibility of the finger would improve the function and diminish the pain. This goal has not been achieved, and not only has causalgia persisted, impairing function, but the transferred skin and donor area also became painful. Consequently it seems necessary to treat the pain of anaesthetic and painful hands before considering the restoration of sensibility.

INDICATIONS

We have used this operation for two reasons: the treatment of insensitive digits and reconstruction of the thumb. Details of our ten cases will be published in another article.

Treatment of insensitive fingers—Anaesthesia of the fingers may result from paralysis of the median or ulnar nerves or from destruction of digital nerves.

Paralysis of the median nerve—In a patient eight years after section of the median nerve at the wrist, a neurovascular skin island was taken from the medial side of the ring finger and transplanted to the index finger; the entire index finger regained sensibility. In such a patient it would be more logical to transfer the sensitive transplant to the thumb, giving a sensitive grip between the thumb and all the opposite fingers.

Paralysis of the ulnar nerve—A sensitive cutaneous transplant can be taken from the medial side of the middle finger and transferred to the medial side of the little finger. This procedure has been performed in two patients. In the first the island was transferred to the little finger which was stiff and retracted. The sensibility of the transplanted skin has a protective effect in spite of the fact that it is still felt as of the third finger and that there is almost no extension of sensibility around the island; but this retracted finger is rarely used.

In another similar case we preferred to amputate an insensitive and stiff little finger and at the same time transferred from the middle finger a sensitive cutaneous transplant to the medial side of the ring finger, while the sublimis tendon of the little finger was transplanted onto the dorsal expansion of the ring finger. In a few weeks the entire ring finger regained sensibility which was mostly felt as arising from the ring finger.

Destruction of digital nerves—We operated on four patients, the thumb in three and the index in the fourth.

A sensitive cutaneous transplant can be taken from the medial palmar aspect of the middle or ring finger and transferred to the thumb or another finger which has had both digital nerves destroyed. These patients have less good functional results, probably because of scar tissue in the fingers.

In addition to the two patients mentioned who had painful hands before operation and remained so after (one has since improved after a thoracic sympathectomy), a third patient developed pain at the level of the passage of the pedicle under the palmar incision at the base of the thumb; a secondary operation has freed the pedicle and a rotation cutaneous flap has avoided further irritation.

One patient with an anaesthetic and painful thumb (Fig. 2) had the two neuromata of the collateral nerves resected and the proximal part of each nerve transferred through the thenar muscles to the dorsal aspect of the hand with good results. Then a neurovascular skin island transfer brought excellent restoration of sensibility and function.

Reconstruction of a sensitive thumb—In three cases we have combined osteoplastic reconstruction of a thumb with the transfer of a hetero-digital cutaneous transplant; this technique requires several operations.

Preparation of a tube pedicle flap—It is necessary to fashion a flap of a suitable length. The most suitable donor area is the infra-clavicular region, but the tube can be raised from the abdomen or the upper limb. If the tube is not too long it is possible to make a direct implant on the thenar eminence without incurring excessive risk, but it is safer to do this in two stages. During this transfer it is important that the longitudinal suture line of the tube is on the palmar surface, because it is at this site that the island transfer will be placed.

Separation of the tube is done three weeks later.

Inclusion of the bone graft and of the skin island transfer—This is performed after complete healing of the tube. It consists of three stages as follows: 1) *Opening of the tube.* The tube is opened along the line of the suture exposing the end of the bone into which a bone graft will be placed. 2) *Inclusion of the bone graft.* The graft is usually taken from the iliac crest. It is fixed by pushing the tip of the tapered graft inside the medullary canal of the first

metacarpal. The length of the graft and of the reconstructed thumb depends on the site of amputation; the aim is to provide a thumb sufficiently long to allow easy opposition. Because it has no joint, the thumb must be a little shorter than normal. Other procedures often result in either a thumb which is too short or a thumb which is too long for the available blood supply and suffers trophic changes. 3) *Transfer of the island flap.* The procedure is the same as described for the other fingers except that it should be larger—four to five centimetres long and about one centimetre broad. The neurovascular skin transfer is introduced into the tube along the line of previous suture allowing easy closure after the bone graft has been sited.

The reconstructed thumb is immobilised in plaster-of-Paris for about one month. In all cases union has been rapid.

The result in these three patients has been equally satisfactory in prehension and sensibility. The nutrition also has become excellent. The transfer of a good blood supply is probably the explanation of the rapid consolidation of the bone graft and the lack of trophic changes. Any osteoplastic reconstruction of the thumb already performed can be benefited by the transfer of such a neurovascular island. In spite of its relative complexity this new procedure of thumb reconstruction seems to have useful applications.

SUMMARY AND CONCLUSIONS

In ten cases definitive loss of sensibility in an important territory of the hand has been treated by a hetero-digital, neurovascular skin island transfer. Operative technique and results obtained are reported. Although not enough patients have been treated to allow us to give precise indications for the procedure, two such indications clearly emerge: 1) the treatment of insensitive digits; 2) the reconstruction of the thumb or fingers. The procedure could probably be used elsewhere than in the hand.

REFERENCES

LITTLER, W. (1960): Neurovascular Skin Island Transfer in Reconstructive Hand Surgery. In *Transactions of the International Society of Plastic Surgeons.* Second Congress, London 1959, p. 175. Edited by A. B. Wallace. Edinburgh and London: E. & S. Livingstone Ltd.

MOBERG, E. (1955): Transfer of Sensation. *Journal of Bone and Joint Surgery*, **37-A**, 305.

MOBERG, E. (1958): Objective Methods for Determining the Functional Value of Sensibility in the Hand. *Journal of Bone and Joint Surgery*, **40-B**, 454.

TUBIANA, R., and DUPARC, J. (1959): Opération palliative pour paralysie sensitive à la main. (Rapport de R. Merle d'Aubigné.) *Mémoires de l'Académie de Chirurgie*, **85**, 666.

TUBIANA, R., and DUPARC, J. (1960): Un procédé nouveau de reconstruction du pouce. *Annales de Chirurgie Plastique*, **5**, 287.

THE ASSESSMENT OF HAND FUNCTION AFTER PERIPHERAL NERVE INJURIES

RUTH E. M. BOWDEN and J. R. NAPIER, LONDON, ENGLAND

From the Royal Free Hospital School of Medicine, London

The diagnosis, follow-up and final assessment of a peripheral nerve injury includes a detailed examination of the range of movement of individual joints, the power of individual muscles and the recovery of the various modalities of sensibility. Objective methods of examination and recording of results of such observations have been described by Seddon (1949). A numerical assessment of motor and sensory recovery suggested by Highet in an unpublished memorandum to the Nerve Injuries Committee of the Medical Research Council has proved of great value. Using this scheme, Zachary (1954) was able to analyse the functional

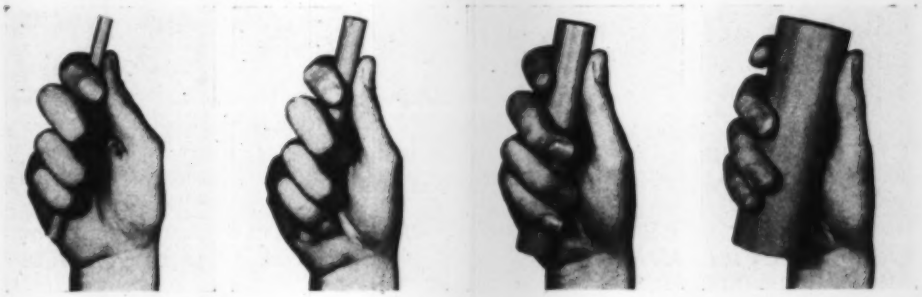


FIG. 1

Power grip; note the variation in posture of the wrist and digits with cylinders of different diameters.

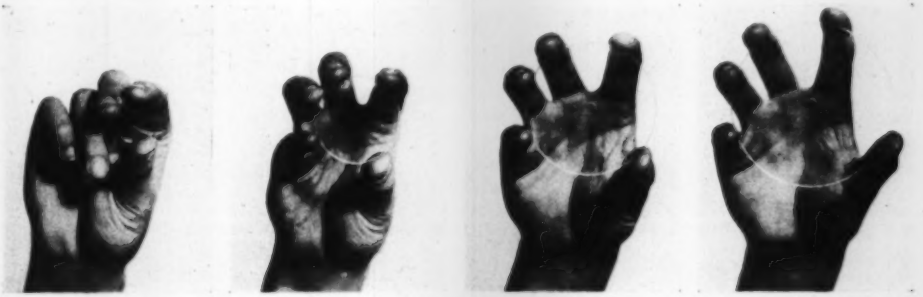


FIG. 2

Precision grip; note the variation in posture of the wrist and digits with Perspex discs of different diameters.

effects of delay in repair and of the level and length of lesions in different nerves. Valuable as these methods of recording results have proved, they are, to some extent, arbitrary and artificial in terms of everyday use of injured limbs. Whilst it is possible to make an indirect assessment of functional recovery on the basis of such data, this requires considerable experience and judgment (Davies 1949). There is clearly a need for a series of simple, repeatable tests of the function of the hand as a whole by which the patient's capabilities may be assessed directly. Want of such tests forces the examiner to place too much weight on the patient's own valuation

FIG. 3
Power and precision grip combined in a single posture

of his disability, an estimate which is an indispensable part of the history but is seldom dispassionate; the enterprising and resourceful make light of their difficulties and others, for a variety of reasons, make heavy weather of them. Moberg (1958) has shown how such tests may be employed for assessing sensory function.

It has been suggested that the movements of the human hand, as a whole, can be regarded as prehensile and non-prehensile and that the prehensile movements which comprise the most exact and intricate movements of the hand fall into two broad groups which are described by the terms power grip and precision grip (Napier 1956); that these two terms encompass the whole range of prehensile movement is attested by the observation that, should the hand be arrested during prehensile activity, it exhibits some phase of one or other grip, or sometimes a combination of the two (Figs. 1 to 3). In a *power grip* the object is held in a clamp formed by the flexed fingers and palm, the thumb acting as a stabiliser (Fig. 1) and a reinforcement of the clamp. In the *precision grip* the object is pinched between the flexor surfaces of the fingers and the opposing thumb (Fig. 2). The terms, like those of flexion and extension, can be used in a dynamic as well as a static sense to describe both a movement and a posture. The position of the wrist plays a significant part; in a power grip it is held either in neutral position or in very slight dorsiflexion, the degree of ulnar deviation increasing with the size of the object held (Fig. 1); in a precision grip the wrist is markedly dorsiflexed and the thumb lies in line with the radius (Fig. 4).

The purpose of this paper is to record results of a series of tests for power and precision grip in a group of patients with peripheral nerve injuries affecting the hand.

FIG. 4
The dorsiflexion of the wrist in a fine precision grip.

CLINICAL MATERIAL

One hundred and fifty-four patients were examined: 152 were men and two women and their ages at the time of injury ranged from seventeen to forty years. With two exceptions all have been treated in one of the special centres set up for the care of peripheral nerve injuries during the war and all were subsequently followed up by both of us from 1947 to 1954 at a clinic instituted at the request of the Medical Research Council, at the Royal Free Hospital, Lawn Road. Full records from the time of injury were available for all patients.

The grouping of the patients accords with the nerve affected; a summary of these groups is shown in Table I.

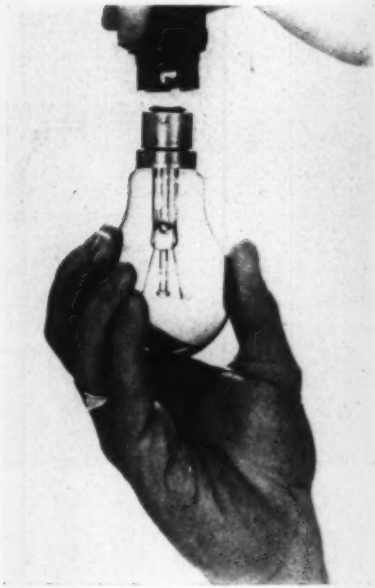


FIG. 5

FIG. 6

Figure 5—The lugs of the electric light bulb are being engaged in the bayonet fitting of the socket (precision grip). Figure 6—The lugs are being locked home (power grip).

FIG. 7

FIG. 8

Case 1,967. Low lesion in continuity of ulnar nerve. Figure 7—Power grip. Figure 8—Precision grip.

TABLE I

SUMMARY OF NERVE INJURIES STUDIED

Affected nerve	Number of patients			Range of ages at time of injury (*years*)	Nature of injury				Sutures	Lesion in continuity
	Total	Male	Female		Gunshot wound	Laceration	Fracture	Pressure		
Ulnar . .	59	59	—	18–40	55	4	—	—	41	18
Median . .	32	31	1	19–35	28	3	—	1	25	7
Radial including posterior-interosseous .	14	14	—	17–37	12	1	1	—	12	2
Median and ulnar	34	33	1	18–35	30	4	—	—	21	13
Median and radial	5	5	—	21–31	5	—	—	—	2	3
Median, ulnar and radial . .	10	10	—	20–30	10	—	—	—	4	6

METHODS

A full history was taken and included information about employment and hobbies. The range of passive movement of individual joints, the presence or absence of contractures of muscles, power of individual muscles and results of sensory stimulation with 1 gramme von Frey hairs and pinprick, were recorded in all cases. Voluntary power was recorded on the M.R.C. scale* (Seddon 1949). Some patients were given a more detailed sensory examination employing graded stimuli and tests for two-point discrimination. Stereognosis and ability to judge weight were tested by the use of paired plastic shapes, one of each pair having a weight embedded in its substance. The ability to judge textures was tested with a range of materials or, if the patient was unfamiliar with textiles, with graded samples of glass paper. Sensory discrimination was tested in both hands.

Power grip was tested by using wooden or plaster cylinders, approximately six inches long and of diameters ranging from half an inch to two and a half inches. For precision grip three balls were employed; the smallest was a marble, the second a squash ball and the largest a rubber ball three and a half inches in diameter; when tests for the finer grades of precision were required the patient was asked to pick up a pin or a needle. The stability of grip and its departure from normal were noted and, when possible, progress was recorded photographically (Figs. 18 to 26).

As already pointed out, it is the purpose of the movement rather than the shape of the object which influences the choice of grip employed (Napier 1956). For example, a wooden cylinder may be held in either of the two postures: as a pen it is held in a precision grip and as a hammer in a power grip. Similarly, a sphere such as an electric bulb is held in a precision grip whilst the lugs are being engaged in the bayonet fitting and in a power grip as it is locked home (Figs. 5 and 6).

RESULTS

Ulnar nerve injuries—Power grip was more affected than precision grip (Figs. 7 and 8) and, as expected, the more complete the palsy the greater was the disability. However, even in low

* 0=No movement detected. 1=A flicker of movement in the muscle belly. 2=Movement of the relevant joint with gravity eliminated. 3=Movement of the joint against gravity. 4=Movement against resistance. 5=Movement against resistance clinically indistinguishable from normal.

FIG. 9

Case 958—Suture of ulnar nerve 11 centimetres above the medial epicondyle. Action of flexor pollicis longus compensating for paralysed adductor pollicis. (Froment's sign.)

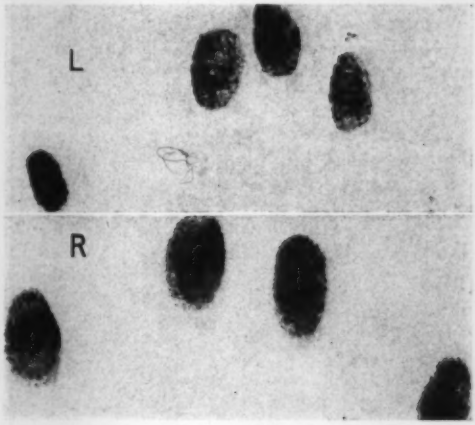


FIG. 10

Ulnar nerve lesion. Fingerprints demonstrating R—the normal hand; L—the affected hand. Note the diminished spread of the digits and trophic changes in the left hand.

lesions with intact long flexors, disturbance of power grip was severe unless the intrinsic muscles were capable of contracting against resistance. Disturbance of power grip was most marked when gripping small cylinders. The three factors responsible for the inefficiency of the grip were, firstly, the inability to wrap the fingers fully round the object, secondly the failure of elevation of the hypothenar eminence, and thirdly the ineffective clamping action of the thumb due to weakness or paralysis of adductor pollicis (Fig. 7). The loss of adductor pollicis is only partly compensated for by the action of flexor pollicis longus (Fig. 9).

The impairment of precision grip for large objects was due to a lack of spread of the digits, the result of weakness or paralysis of abductor minimi digiti and of the dorsal interossei (Fig. 10). Impairment for small objects (Fig. 11) was due to instability of the thumb and the unrotated index finger, the results of paralysis of adductor pollicis and the first dorsal and second palmar interossei respectively.

Contractures of flexor digitorum profundus to the two inner digits and of the interossei, with or without secondary changes in the metacarpophalangeal and interphalangeal joints, aggravated the handicap with respect to power grip in particular (Figs. 12 and 13).

A " lively " knuckleduster splint (Capener 1946) improves the grip (Figs. 14 and 15) and lessens the tendency to the formation of contractures (Bowden 1954).

Median nerve injuries—Interference with power grip was relatively slight in comparison with the serious disturbance of precision grip. In high lesions the grip of small cylinders was impaired by weakness or paralysis of both the long flexors of the index finger (Fig. 16).

FIG. 11

Case 958 (see Fig. 9)—Note the lack of lateral rotation of the index finger and the abnormal position of the thumb due to paralysis of adductor pollicis.

FIG. 12

FIG. 13

Case 972. Figure 12—Low lesion in continuity of ulnar nerve with severe contractions of flexor digitorum profundus. Figure 13—Note the obliquity of grip before and after amputation of the grossly contracted digits.

FIG. 14

FIG. 15

Case 1,163. Figure 14—Suture of the ulnar nerve 8 centimetres above the medial epicondyle. Figure 15—Note the improvement in grip with a lively knuckleduster splint.

A similar loss in the case of the middle finger was usually partly compensated for by the passive pull on flexor digitorum profundus by the intact ulnar half of the muscle. With large cylinders defects of the grip were more evident, because even in low lesions with intact flexors of the digits loss of abduction and rotation of the thumb prevented it from stabilising and reinforcing the grip (Fig. 17).

Precision grip was grossly impaired even when the long flexors were intact. The main factor on the motor side was loss of abduction and rotation at the carpo-metacarpal and

FIG. 16

FIG. 17

Figure 16. Case 799—Suture of the median nerve 22 centimetres above the medial epicondyle. Note i) the signpost deformity which impairs the stability of the power grip; ii) the unrotated thumb. Figure 17. Case H.10—Suture of median nerve at wrist in March 1952. (The distribution of the nerve in this case was anomalous; note the small area of loss of sensibility in Figures 18 to 26; flexor pollicis brevis was partially supplied by the ulnar; abductor pollicis brevis and opponens were wholly supplied by the median nerve.) Impairment of the power grip as a result of lack of rotation of the thumb.

metacarpo-phalangeal joints of the thumb due to paralysis of the abductor pollicis brevis. In median nerve injuries the loss of cutaneous sensibility was an additional and significant factor.

Figures 18 to 26 illustrate the progress of a patient after suture of the median nerve at the wrist. The abductor pollicis brevis and the opponens pollicis were paralysed but the flexor pollicis brevis was, in this instance, wholly supplied by the ulnar nerve. The small area of sensory loss was due to the unusually large cutaneous distribution of the ulnar and radial nerves. The first signs of a return towards a normal pattern of function appeared when the opponens pollicis and abductor pollicis brevis were contracting against gravity (Figs. 22 and 25) and there was still a slight deficiency when they were acting against resistance. Although only two of the intrinsic thenar muscles were affected the disability was great.

Contractures of the active adductor pollicis and of the capsules of the joints of the thumb, and overstretching of abductor pollicis brevis counteracted the results of reinnervation in a number of patients. A relatively minor limitation of movement in joints of the thumb—particularly the metacarpo-phalangeal joint—had a disproportionately serious effect on function (Napier 1952).

Radial and posterior interosseous nerve injuries—Both types of grip were affected and the defect was more apparent with large than with small objects. Impairment of power grip was due to the wrist drop, the absence of synergic activity in the extensors of the wrist preventing the

FIG. 18

FIG. 19

FIG. 20

FIG. 21

FIG. 22

FIG. 23

FIG. 24

FIG. 25

FIG. 26

Case H.10—Figures 18 to 20 show progress of recovery of tactile sensibility. Figures 18 and 19—Loss of response to No. 3 von Frey hair; Figure 20—No loss of response to Nos. 2 and 3, but to No. 1 hair only. Figures 21 to 23 and 24 to 26 show improvement in coarse and fine precision grip.

more efficient flexion of the digits (Fig. 27). When the radial extensors of the wrist were active, weakness of ulnar deviation due to imbalance between the abductors and adductors of the wrist reduced the efficiency of grasping large cylinders.

The loss or weakness of extension of the wrist was the main factor contributing to impairment of the precision grip; paralysis of abductor pollicis longus was a secondary factor, particularly when the object was large and necessitated wide abduction of the thumb.

An effective splint corrects the wrist and finger drop, and compensates for the loss of extension of the thumb and paralysis of abductor pollicis longus. In some patients, however, crippling contractures had developed in all the extensors after wearing, in the early stages, a certain type of cock-up splint which virtually immobilised the wrist. These contractures in the extensors of the thumb were serious for they significantly limited abduction and rotation and flexion of the joints of the digit. In long established cases of radial palsy where there are no contractures and there is little danger of them developing at the later stage, a fixed cock-up splint can, however, materially increase the efficiency of grip (Fig. 28).

Combined nerve lesions—The commonest form of combined lesion is that affecting both median and ulnar nerves (Nicholson and Seddon 1957) (Table I). Even in low lesions in which the long flexors of the wrist and digits are spared, disablement of prehensile function is considerable. The thumb deprived of all intrinsic muscles can contribute little towards prehension (Figs 29 and 30). Both power and precision grip are equally affected and the hand is functionally

little more than a hook. In high lesions even this hook-like action may be impossible owing to the presence of contractures in the long flexor muscles that may prevent the digits from being sufficiently extended to contain a cylindrical or spherical object. Considerable functional improvement can be obtained by the use of a suitable splint (Figs. 31 and 32) that corrects the paralytic deformity of the thumb.

FIG. 27
Case 786—Impaired power grip due to a wrist drop following irreparable damage to the radial nerve.

FIG. 28
Case 896—Lesion in continuity of the radial nerve with poor recovery. The patient was unwilling to submit to a tendon transplant. Note the effective grip when wearing a cock-up splint designed to meet his particular requirements.

Other combined lesions have been studied including median and radial nerve lesions and median, ulnar and radial lesions, but they will not be described, as the disabilities associated with these lesions are embodied in the accounts given above of single nerve lesions.

DISCUSSION AND CONCLUSIONS

The effects of peripheral nerve injuries upon skilled and unskilled movements are generally understood and have been summarised recently (Bowden 1958). The part played by the median nerve in prehensile movements of precision and by the radial nerve in stabilising and determining the position of the wrist for prehensile function are well known. Less well known are the effects of ulnar nerve lesions on the functional efficiency of the hand. Whilst there is full recognition of the loss of skilled percussive movements (for example, those used in typing)

that follow damage to the ulnar nerve, the effect upon prehension may be less well appreciated. It is generally understood that an ulnar nerve lesion in a skilled worker is not an insuperable disability and it might be supposed that it constitutes even less of a disability in an unskilled or manual worker. This, however, is far from the truth, for with certain reservations mentioned below, the ulnar nerve is the nerve of the power grip. The stability of the grip depends on the pressure and counter-pressure provided by the fourth and fifth digits and the hypothenar eminence on the one side and the counter-pressure of the thumb on the other. This point is illustrated by the history of a Metropolitan Water Board turn-cock whose right-sided power grip was impaired due to the presence of an ulnar paresis. Although right-handed, this patient found it necessary to use his left hand for the preliminary loosening and final tightening of the cocks against the resistance of the thread; the intermediate phases of the operation which required little power were performed by the dominant though weaker right hand.

FIG. 29

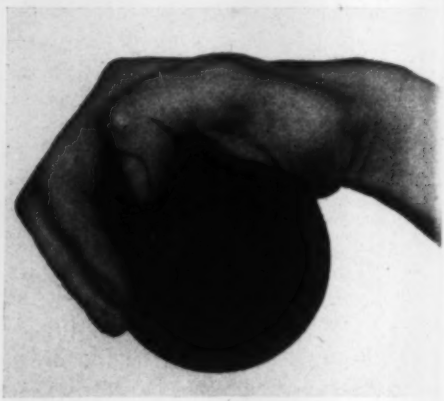


FIG. 30

Case 745. Figures 29 and 30—High median and ulnar nerve lesions resulting in gross disturbance of the power and precision grips.

The findings in this study suggest that, given a stable wrist, the ulnar nerve is the nerve of the power grip and the median the nerve of the precision grip. The concept of a complete neurological and functional dichotomy, however, breaks down on several points. Firstly, adductor pollicis (ulnar nerve) is used in both grips to move the thumb towards the index finger. Loss of this muscle affects power and precision to different degrees. In the power grip the role of the thumb in applying counter-pressure is severely impaired, while in the precision grip, in which less force is required of the thumb than the index finger, the loss of the muscle is not so serious. Secondly, the thenar muscles (median nerve), which are clearly of critical importance in the precision grip, also contribute to the stability of the metacarpo-phalangeal joint during power gripping. Some loss of power, particularly with large cylinders, can be observed in the power grip where the thumb requires to be considerably abducted; with more slender cylinders the disability is less marked. Thirdly, the flexor pollicis longus (median nerve) is of critical importance in the precision grip but also plays an important part in the power grip. The loss of flexor pollicis longus can be compensated for in the power grip by hyperextension of the distal phalanx and the use of the thumb as a whole, rather than the terminal phalanx alone, to provide the necessary counter-pressure. Thus, although the loss of flexor pollicis longus affects the efficiency of both grips, it has its most profound effect upon the precision grip. Lastly, the first dorsal and second palmar interossei (ulnar nerve) contribute to the stability of the index finger during index-thumb opposition; the loss of

these muscles reduces the strength of the pinch movement and promotes the use of the middle finger during precision movements as a prop and stay to the index finger.

Although the two grips are not fully discrete from the point of view of the nerve supply of the component muscles, it is apparent from the foregoing results that *functionally* the brunt of an ulnar nerve lesion falls on the power grip and that of a median nerve lesion upon the precision grip. Therefore, in spite of the absence of clear-cut neurological dichotomy, this

FIG. 31
Case 1,782—Severe lesion in continuity of the median nerve and suture of the ulnar nerve 8 centimetres above the medial epicondyle.

FIG. 32
Case 1,782—Note the effect upon the thumb of a modified Highet type of median nerve splint.

study provides clinical support for the concept that the prehensile movements of the hand as a whole may be regarded in terms of two fundamental movement complexes.

The use of the tests has demonstrated that an apparently mild contracture of the muscles and of the joint capsules in the hand, and in particular of the thumb, has a grave effect upon function. They have shown the deleterious effect of the insidious, and at times unnoticed, contractures of the interossei and capsules of the metacarpo-phalangeal joints, thus emphasising

the need to prevent contractures by passive movements and by active or " lively " splinting (Capener 1946) which not only corrects the paralytic deformity, but also encourages repeated daily use of the hand.

The tests described do not provide a short cut to diagnosis or prognosis but it is suggested that they are a useful adjunct to the full routine motor and sensory examination, particularly in the later stages when the patient's capacity for work is under assessment. They offer a simple, repeatable and objective method of estimating the prehensile function of the hand as a whole. The need for such functional tests has already been stressed by Moberg (1958). The defects of prehension can be analysed in detail in each case and the effectiveness of splints tested. The patient can be helped to select the optimum size for handles of tools and utensils and to choose a suitable definitive employment. The prehensile requirements of any manual employment can be studied in terms of power and precision grip.

SUMMARY

1. Power and precision grip (Napier 1956) were tested in 154 patients with nerve injuries.
2. The results are described, illustrated and discussed and it is suggested that these tests provide a simple, repeatable and objective method of assessing prehensile function of the hand as a whole.

Grateful thanks are due to the Governors of the Royal Free Hospital through whose kindness it was possible for us to conduct a follow-up clinic for peripheral nerve injuries from 1947–54 inclusive; to the Medical Research Council and the Endowment Fund of the Royal Free Hospital for generous financial support. It is a pleasure to record appreciation of Mrs E. Broome, secretary and research assistant, and Mrs P. Thomas, Miss F. Ellis and Mr A. L. Wooding of the Photographic Departments of the Royal Free Hospital School of Medicine and St Thomas's Hospital Medical School. Grateful acknowledgment is made to the Editor of the *British Journal of Physical Medicine* for permission to use Figures 14 and 15.

REFERENCES

BOWDEN, R. E. M. (1954): Factors Influencing Functional Recovery. In *Peripheral Nerve Injuries*. Special Report Series Medical Research Council, Number 282, p. 298. London: Her Majesty's Stationery Office.

BOWDEN, R. E. M. (1958): *Peripheral Nerve Injuries*, Chapter 4. London: H. K. Lewis & Company.

CAPENER, N. (1946): Physiological Rest, with Special Reference to Arthritis and Nerve Lesions and to the Manufacture of Appliances. *British Medical Journal*, **ii**, 761.

DAVIS, D. R. (1949): Some Factors Affecting the Results of Treatment of Peripheral Nerve Injuries. *Lancet*, **i**, 877.

KIRK, T. S. (1924): Some Points in the Mechanism of the Human Hand. *Journal of Anatomy*, **58**, 228.

MOBERG, E. (1958): Objective Methods for Determining the Functional Value of Sensibility in the Hand. *Journal of Bone and Joint Surgery*, **40–B**, 454.

NAPIER, J. R. (1952): The Attachments and Function of the Abductor Pollicis Brevis. *Journal of Anatomy*, **86**, 335.

NAPIER, J. R. (1956): The Prehensile Movements of the Human Hand. *Journal of Bone and Joint Surgery*, **38–B**, 902.

NICHOLSON, O. R., and SEDDON, H. J. (1957): Nerve Repair in Civil Practice. *British Medical Journal*, **ii**, 1,065.

SEDDON, H. J. (1949): War Injuries of Peripheral Nerves. *British Journal of Surgery. War Supplement*, **2**, 329.

ZACHARY, R. B. (1954): Results of Nerve Suture. In *Peripheral Nerve Injuries*. Special Report Series Medical Research Council, Number 282, p. 354. London: Her Majesty's Stationery Office.

BRACHIAL PLEXUS INJURIES: TREATMENT OF THE FLAIL ARM

P. M. YEOMAN and H. J. SEDDON, LONDON, ENGLAND

From the Institute of Orthopaedics, University of London

Total and irrecoverable paralysis of the arm caused by a traction injury of the brachial plexus is a very grave affair. So that no time and effort may be wasted on fruitless conservative treatment it is imperative that in all cases in which the arm is totally paralysed the prognosis should be determined at the earliest possible moment. Furthermore, the ultimate outlook of the patient is sensibly improved if there is not too long an interval between the injury and the definitive treatment of the flail limb.

We are indebted to Bonney (1954) for showing that the level of the damage in relation to the posterior root ganglia can be demonstrated by tests which indicate whether the peripheral axons of the ganglion cells are intact. If they are, then the nerve roots have been avulsed from the cord and no recovery is possible. Bonney (1959) also reviewed other unfavourable factors which are: 1) a high-velocity injury; 2) severe spasmodic pain; and 3) Horner's syndrome (see also Barnes 1949), which has long had a sinister reputation.

When there are indications that some or all of the roots are damaged distal to the ganglia it has been our custom to explore the plexus. In such of the nerve trunks as are found to be in continuity there is a possibility of recovery. If they are ruptured repair is impossible and the definitive treatment—such as it is—should be started without delay.

If the inquiry is pursued methodically the prognosis can be settled within eight weeks from the time of injury.

TABLE I

MODE OF INJURY

	Number of patients
Motor cycle	27
Pedal cycle	6
Car	1
Caught in machine	1
Tobogganing	1
Total	36

METHODS OF TREATMENT

There are two opposed methods of treatment of the flail upper limb: firstly, reconstruction by tenodesis of the fingers, a posterior bone block at the elbow and arthrodesis of the shoulder (Hendry 1949); secondly, simultaneous amputation through the arm and arthrodesis of the shoulder, a method used by Perkins (1945) during the second world war, which one of us (H. J. S.) learned from him. A comparison of the results of these methods was suggested by Seddon (1949) and this is now possible.

THE PATIENTS

The records of 280 patients with traction lesions of the brachial plexus were available for study. These included patients who had been treated at the Oxford Nerve Injury Centre between 1941 and 1948 (this unit was transferred to the Royal National Orthopaedic Hospital in 1948) and those treated at the Royal National Orthopaedic Hospital between 1948 and 1958. All those with incomplete lesions or with some recovery were excluded, leaving a total of forty-two patients with complete and permanent paralysis.

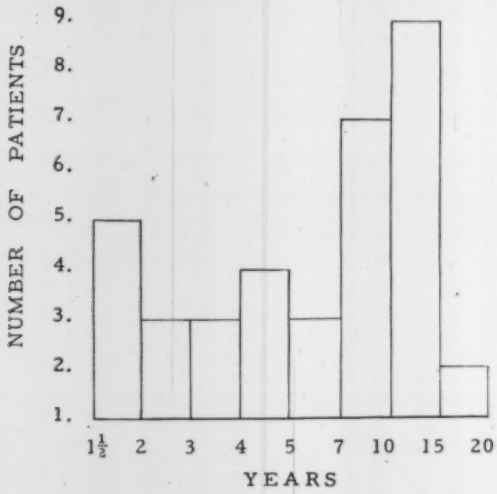


FIG. 1
Length of follow-up since accident.

It has been possible to trace thirty-six of them and all were seen and examined by one of us (P. M. Y.). All were males, mostly between sixteen and twenty-five years of age at the time of injury, which in three cases out of four was due to a motor-cycle accident (Table I). The time interval between the accident and follow-up varied from eighteen months to eighteen years (Fig. 1); at examination most of the patients were between twenty-six and forty years old. The dominant limb was injured in twenty-five.

METHOD OF ASSESSMENT

The method of grading was as follows: *satisfactory*: uses the limb habitually; *fair*: uses the limb or stump occasionally; *failure*: never uses limb, stump or prosthesis.

RESULTS

The series has been divided into three groups according to the method of treatment.

Amputation—There were seventeen patients in this group. Amputation through the arm with simultaneous arthrodesis of the shoulder was performed in thirteen. In two cases arthrodesis of the shoulder had been performed previously, in one as part of a reconstruction programme, in the other combined with an amputation through the forearm; amputation through the arm was carried out subsequently at the request of the patients. Two patients had an amputation through the arm at their own request in order to remove a useless impediment. Among these seventeen patients there were five satisfactory results (Table II).

Reconstruction—There were eight patients in this group. The operations performed included tenodesis of the fingers, arthrodesis of the wrist, posterior bone block at the elbow and arthrodesis of the shoulder. One patient subsequently had an amputation through the arm, and is also included in the amputation group. There was no satisfactory result in this group, and only one was fair.

No operation—There were twelve patients in this group. There was not one in which the limb could be described as satisfactory, but five were fair.

The results in the three groups are summarised in Table II. Amputation through the arm with arthrodesis of the shoulder gave the best results, although only nine out of the fifteen patients were using an artificial limb. The results of so-called reconstruction were worse than when operation was withheld.

TABLE II

FUNCTIONAL RESULTS

Result	Group 1: Amputation of arm		Group 2: Reconstruction	Group 3: No operation
	With arthrodesis of shoulder	Without arthrodesis		
Satisfactory	5	—	—	—
Fair	9	1	1	5
Failure	1	1	7	7
Total	15	2	8	12

One patient in Group 2 subsequently had an amputation and is also included in Group 1.

FACTORS INFLUENCING THE RESULTS

Interval between injury and amputation—A long interval between the injury and amputation had an adverse effect on the patient's outlook. The average interval between the injury and operation in those patients who were using an artificial limb was sixteen months, whereas in those who were not using an artificial limb it was three years and seven months. A patient is liable to become completely " one-handed " after about two years, even if the dominant limb is injured. It is doubtful whether any operation, other than for the relief of pain, is indicated after such an interval.

A long period of disuse causes osteoporosis, and in the head of the humerus this can seriously embarrass the surgeon embarking on an arthrodesis of the shoulder. In two cases the operation was difficult. In one amputation-arthrodesis fusion occurred eventually: in the other it did not, the patient could not use a prosthesis because of the pain in the shoulder, nor would he consent to a further operation.

We have already observed that it is possible to determine the prognosis by the eighth week after injury and the reader may well ask why, in our cases that turned out most favourably, the delay before amputation averaged as much as sixteen months. There were three reasons for this. Some of the patients were dealt with before we were informed about methods for establishing the prognosis; some did not come to us until months after the accident; and some patients were understandably reluctant to submit to the irrevocable step before the passage of time had convinced them that no recovery could be hoped for.

Length of stump—The average length of the arm stump was eight inches from the tip of the acromion. This was about right in the average adult and all of our patients were adults. The conventional mechanical elbow joint requires a clearance of four and a half inches below the stump, and the adult arm is twelve or thirteen inches long. The humerus should not be

flexed more than 20 degrees in relation to the medial border of the scapula or in more than 25 degrees abduction. A greater angle of flexion or abduction makes it not only difficult to fit a prosthesis but uncomfortable to use.

One patient with a four-inch stump was able to use his artificial limb only for steadying the steering wheel of a car. A short stump is useless for holding papers or books against the chest wall. This function was often present in those patients who had retained their limbs and kept their hands in their pockets; this had led to an adduction contracture of the shoulder which, as it turned out, was useful.

Physiotherapy—In general, patients with brachial plexus injuries derive great benefit from passive movements of the joints and elevation of the limb in the early stages. The residual stiffness and contracture of the fingers in those who retained their limbs was directly related to the early swelling of the hand which elevation and passive movements would have prevented. Contractures and stiffness did not develop later in hands which were kept mobile at first. But physiotherapy is valueless for a totally paralysed limb when it is certain that no useful recovery can occur; in fact there were instances in which a prolonged course of physiotherapy had delayed the patient's return to work either by engendering a baseless optimism or simply by the time he was required to spend attending hospital for treatment.

Pain—Severe pain, constant and radiating down the limb, was not improved by any operation on the arm itself, and its persistence after operation discouraged the patient from using an artificial limb, stump or reconstructed arm.

Mechanical ability—Patients who had been good with their hands were keen to regain what function they could on the injured side so that they might if possible return to their previous employment or continue with their various pastimes. By contrast the office worker with perhaps a higher standard of education but no special mechanical ability was not necessarily

TABLE III

RESULT RELATED TO PATIENT'S MECHANICAL ABILITY (FIFTEEN PATIENTS WITH AMPUTATION-ARTHRODESIS)

Case number	Employment		Pain	Prosthesis worn	Result
	Before accident	After accident			
1	Bench machine worker	Bench assembly worker	Occasionally severe	Yes	Satisfactory
2	Bricklayer	Garage hand	Very occasionally severe	Yes	Satisfactory
3	Driver/fitter	Decorator	Very occasionally severe	Yes	Satisfactory
4	Engineer	Welder	Very occasionally severe	Yes	Satisfactory
5	Decorator	Ship's steward	Occasionally severe	Yes	Satisfactory
6	Pilot	Mechanic	None	Occasionally	Fair
7	Gardener	Security officer	Moderate continuous	Occasionally	Fair
8	Fireman	Lift attendant	Moderate continuous	Yes	Fair
9	Clerk	Clerk	Very occasionally severe	Occasionally	Fair
10	Clerk	Clerk	Occasionally severe	No	Failure
11	Electrician	Clerk	Occasionally severe	No	Failure
12	Wagon driver	Production manager	None	No	Failure
13	Card jobber	Can packer	None	No	Failure
14	Tailor's cutter	Tailor	Very occasionally severe	No	Failure
15	Navigator	Clerk	Moderate continuous	No	Failure

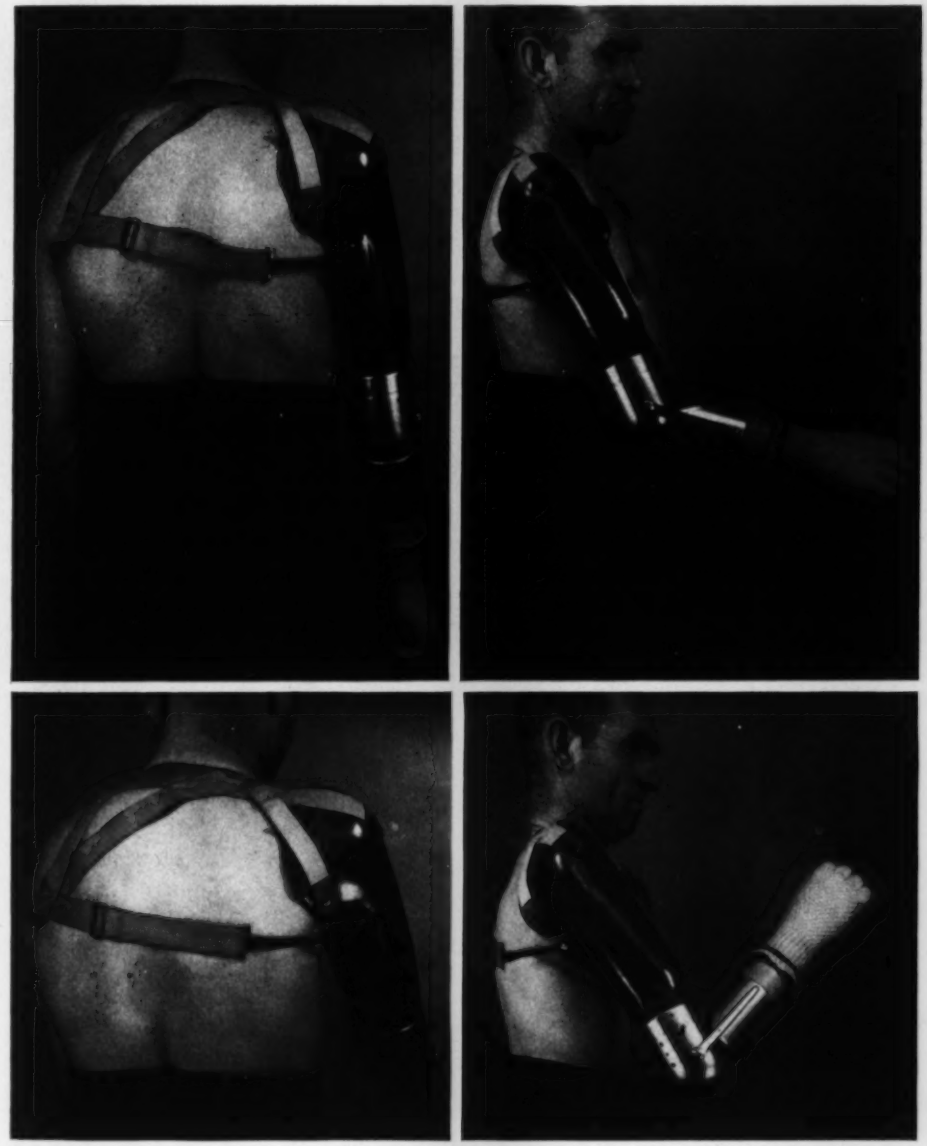


FIG. 2

Shows the shoulder movements that are required to tighten the cable for power transmission to the elbow joint.

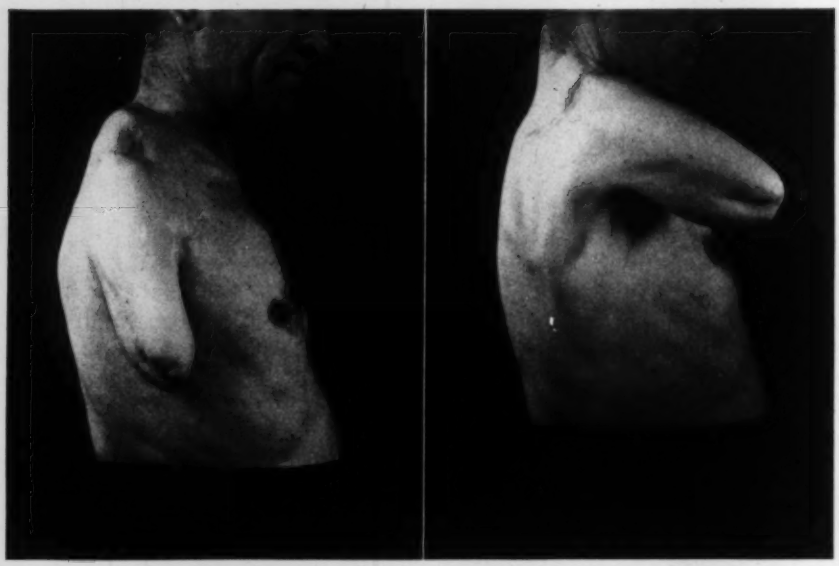


FIG. 3
Contraction of serratus anterior (and trapezius) produces flexion (and abduction) of the stump.

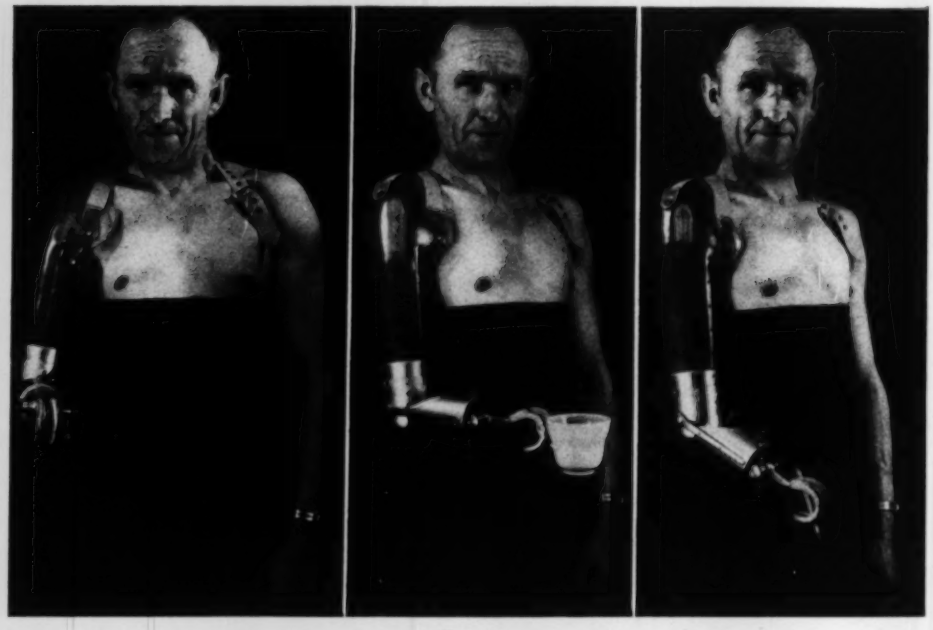


FIG. 4
Strong flexion of the stump is necessary to overcome the friction of the cable for power transmission to the split hook.

improved by operation. The results in the fifteen patients who had undergone amputation-arthrodesis were correlated with their employment before and after injury (Table III). The incidence and severity of pain in these patients are also shown. There was evident mechanical ability in the five satisfactory cases and a lack of it in those described as failures. Pain occurred in most of the fifteen patients and prevented continuous use of an artificial limb in two cases listed as fair.

DISCUSSION

The artificial limb used in these patients consisted of a leather socket moulded to the shoulder and stump, a locking hinge at the elbow, and a terminal rotary segment into which could be fitted an appliance or artificial hand. It was secured to the patient by a harness across the chest and opposite shoulder. The power for controlling flexion of the elbow, or for transmission to a split hook with the elbow locked, was obtained by forward movement of the stump or forward shrugging of the opposite shoulder, either of which produced a pull on the Bowden cable attached to the harness encircling the opposite shoulder (Fig. 2).

Arm amputees generally agree that a split hook is their most useful appliance (Gillis 1957). This was not so in this series of patients because of the restricted forward movement of the stump. The necessary movement of the scapulo-humeral unit was obtained by contraction of the serratus anterior (Fig. 3) and it was usually limited to 30 degrees; only one patient could achieve the proper action of the split hook (Fig. 4).

The main function of the artificial limb in these patients was to steady or hold an object and thereby allow the free, normal arm to manipulate controls. A garage mechanic was able to carry and steady a can of water with a simple hook appliance, thus allowing the free hand to manipulate the radiator cap. Another patient, a conveyor-belt operator, was able to steady and guide boxes along the belt, the normal arm being used to work the controls; he had sufficient control of the artificial limb to push the boxes along if they became wedged. Some patients were able to use a wheelbarrow or hold a spade (Fig. 5). Others used their artificial limbs for steadying the steering wheel of a car; however, this function is not essential because many of the patients could drive a car one-handed with suitable controls.

FIG. 5

Holding or steadying objects is probably the most useful function after amputation-arthrodesis.

Choice of treatment—This review has shown that amputation through the arm with arthrodesis of the shoulder within two years of the accident offers the best prospect of the patient's remaining "two-handed." The amputation should be four and a half inches above the olecranon and the shoulder should be fixed in 20 degrees of flexion and 25 degrees of abduction in relation to the medial border of the scapula.

Because of the lack of sensibility in the hand, reconstructive operations were less favoured than in cases of paralysis from poliomyelitis. The reconstructive programme entails three operations, two of which require prolonged immobilisation in plaster. At the finish the patient

commonly injures his fingers and then keeps the hand permanently in the safety of his trouser pocket.

The most difficult decision is when to withhold operation and when to advise amputation-arthrodesis. Objectively and subjectively amputation of the arm with arthrodesis of the shoulder is probably the better choice: it offers something positive functionally, it removes a useless appendage and it improves the appearance, provided an artificial arm is worn.

The average delay before resumption of work after the accident was fifteen months in patients not treated by operation, and sixteen and a half months in those who had undergone amputation-arthrodesis. It ought to be possible to improve considerably on these figures, but this at least shows that amputation-arthrodesis does not appreciably add to the time away from work.

The functional result will probably be good if the patient is mechanically minded, has only occasional sharp pain in his arm and is favourably impressed after seeing the result of operation in another similarly afflicted patient. It may be better for a clerical worker to retain his flail limb and to accept a " one-handed " existence unless he happens to be manually dexterous.

SUMMARY

1. Thirty-six patients with complete irrecoverable brachial plexus lesions have been studied.
2. Function has been compared after 1) arthrodesis of the shoulder with amputation through the arm, 2) so-called reconstructive procedures, and 3) no operative treatment.
3. The results of reconstructive operations have been so disappointing that we believe that this type of treatment should be abandoned.
4. Amputation-arthrodesis offers a better functional result than either reconstruction or no operation. Its value depends to a considerable extent on the manual dexterity of the patient.
5. A clerical worker who is not mechanically minded is less likely to use an artificial limb, and in this type of patient operation is perhaps best avoided.

We wish to thank Mr I. G. MacKenzie for assistance in the preparation of this paper and the staff of the Medical Records Department of the Royal National Orthopaedic Hospital for their help in tracing patients. This work was aided by a grant provided by the Joint Clinical Research Committee of the Royal National Orthopaedic Hospital and the Institute of Orthopaedics.

REFERENCES

BARNES, R. (1949): Traction Injuries of the Brachial Plexus in Adults. *Journal of Bone and Joint Surgery*, **31–B**, 10.

BONNEY, G. L. W. (1954): The Value of Axon Responses in Determining the Site of Lesion in Traction Injuries of the Brachial Plexus. *Brain*, **77**, 588.

BONNEY, G. (1959): Prognosis in Traction Lesions of the Brachial Plexus. *Journal of Bone and Joint Surgery*, **41–B**, 4.

GILLIS, L. (1957): *Artificial Limbs*, p. 265. London: Pitman Medical Publishing Co. Ltd.

HENDRY, A. M. (1949): The Treatment of Residual Paralysis after Brachial Plexus Injuries. *Journal of Bone and Joint Surgery*, **31–B**, 42.

PERKINS, G. (1945): *Personal communication.*

SEDDON, H. J. (1949): Brachial Plexus Injuries. *Journal of Bone and Joint Surgery*, **31–B**, 3.

REGIONAL OSTEOPOROSIS IN OSTEOID OSTEOMA

A. J. SPENCE, KIRKCALDY, SCOTLAND
and
G. C. LLOYD-ROBERTS, LONDON, ENGLAND

From the Hospital for Sick Children and the Royal National Orthopaedic Hospital, London

We wish to raise once more the question of this dramatic but uncommon condition; our reason is to draw attention to a problem in differential diagnosis between tuberculosis of a joint and an osteoid osteoma close to a joint or at a distance.

Because patients presenting with tuberculosis of a joint are fewer than in former years it is important to realise that the physical signs of arthritis in a major joint may be produced by an osteoid osteoma in an intracapsular or extracapsular position, and may lead to a mistake in diagnosis. The resemblance to tuberculous arthritis may be both clinical—with pain, stiffness and limitation of movement—and radiographic—with regional osteoporosis as commonly seen about a tuberculous joint.

Regional osteoporosis as a feature of osteoid osteoma has not been emphasised before; we have found it mentioned in the literature on only four occasions (Johnson 1955; Goldthwait, Wang, Castleman and Calkins 1955; Davison 1956; and Flaherty, Pugh and Dockerty 1956). Several writers have presented radiographs without commenting on the regional osteoporosis (MacKenzie 1947; Dockerty, Ghormley and Jackson 1951; and Phalen and Patch 1954).

The case histories of six patients are presented, five of whom were admitted to hospital with suspected tuberculous arthritis.

FIG. 1
Case 1—Six months after onset. Osteoporosis of the left femur and left side of the pelvis.

CASE REPORTS

Case 1—A boy of fifteen was seen in September 1954 with pain in various situations in the left lower limb. On clinical examination movements of the left hip were full and only the quadriceps muscle was found to be weak. The radiograph was normal. A month later there was limitation of movement at the left hip; and after a further four months he had 10 degrees

FIG. 2
Case 1—Tomograph showing a nidus in the left femoral neck.

of fixed abduction and 30 degrees of fixed flexion, with an inch of wasting of the thigh. Radiographs showed osteoporosis about the hip (Fig. 1).

The boy was admitted to hospital in February 1955 with a provisional diagnosis of tuberculous arthritis. The erythrocyte sedimentation rate was 144 millimetres in the first hour and the Mantoux test was positive at 1/10,000. A tomograph showed a nidus in the left femoral neck (Fig. 2).

At operation a soft vascular tumour half an inch in diameter was found on the anterior surface of the femoral neck; on histological examination this was characteristic of an osteoid osteoma.

A radiograph two years and eight months after operation showed the bone density restored almost to normal.

Case 2—A girl of thirteen had had pain in the left knee mainly at night for six months and had limped for three months when seen in June 1953. Between the ages of five and ten years she had been operated upon five times for osteomyelitis of the right femur. Examination showed that all movements at the left hip were limited. The erythrocyte sedimentation rate and the white blood cell count were normal and the Mantoux test was negative, but a radiograph showed osteoporosis of the left hip suggesting tuberculous arthritis. Biopsy of an external iliac gland showed normal tissue. Nearly four weeks later a further radiograph showed an increase in the osteoporosis (Fig. 3) and tomographs revealed an area of sclerosis at the base of the left femoral neck (Fig. 4).

At operation a soft, smooth, dark red nodule a third of an inch in diameter was removed from the sclerotic area of the femoral neck. Histologically this was found to be an osteoid osteoma.

FIG. 3
Case 2—Seven months after onset. Osteoporosis about the left hip.

A radiograph sixteen months after operation showed normal density of the bones about the left hip.

Case 3—A girl of eleven complained of pain in the left knee for four months. On admission to hospital in August 1949 there was slight limitation of all movements at the left hip. The erythrocyte sedimentation rate was 16 millimetres in the first hour and the Mantoux test was negative. A radiograph showed a defect in the left femoral neck with surrounding sclerosis (Fig. 5). A provisional diagnosis of osteomyelitis was made. A short plaster spica failed to relieve the pain. Ten months later she was readmitted. She still had pain in the left hip but movements were full. The erythrocyte sedimentation rate had risen to 33 millimetres in the first hour and the white cell count to 11,000 per cubic millimetre. A radiograph showed osteoporosis about the left hip and the defect in the femoral neck (Fig. 6).

FIG. 4
Case 2—Tomograph showing an area of sclerosis at the base of the left femoral neck.

At operation the cavity in the neck of the femur was explored and the material removed proved the presence of an osteoid osteoma.

Nine months after the operation the density of the left femur had returned almost to normal (Fig. 7).

Case 4—A boy of seven had complained of pain in the right thigh off and on for two years and had taken aspirin at night for its relief. When he was examined in June 1954 there was limited rotation of the right hip joint with 20 degrees fixed flexion and wasting of the right gluteal and quadriceps muscles. The erythrocyte sedimentation rate was normal and the Mantoux test negative. A radiograph showed osteoporosis about the right hip with a cortical reaction in the shaft of the femur (Fig. 8).

At operation a block of bone was removed from the femoral shaft. The bone showed a marked cortical reaction, and the presence of an osteoid osteoma was proved histologically.

A radiograph three years and four months after the operation showed a return to normal density of the bones about the right hip.

Case 5—A boy of six was seen in September 1955 when he complained of a painful lump on the dorsum of the left foot first noticed ten months before. This had made him walk badly and the left calf had become wasted. A below-knee walking plaster had been worn for five weeks without relief of pain, and a biopsy of the soft tissues had shown no evidence of tuberculosis although this was suspected. An inguinal gland biopsy also showed no evidence of tuberculosis. The Mantoux test was negative.

On examination the left foot was tender and swollen and there was wasting of the left calf and thigh; a cavo-varus deformity of the foot was present. A radiograph showed generalised osteoporosis of the left tarsus with an island of density, thought to be an abscess with a sequestrum, in the lateral cuneiform bone (Fig. 9).

At operation in October 1955 material was removed from the lateral cuneiform bone and histological examination revealed an osteoid osteoma.

Six months after operation a radiograph showed that the bone density had returned to normal.

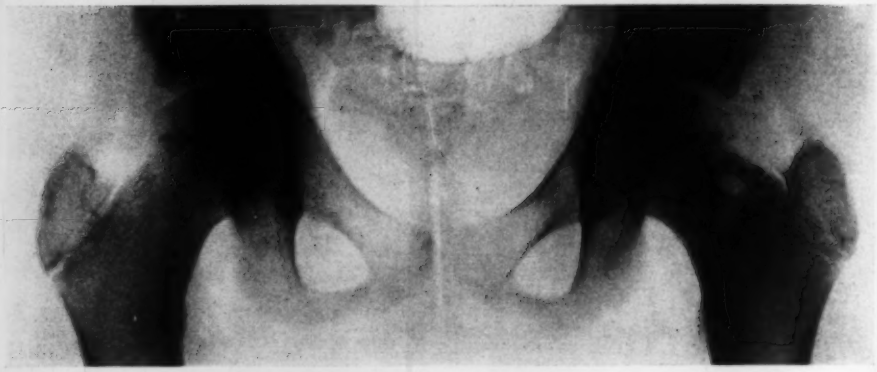


FIG. 5

Case 3—Four months after onset. There is a defect in the left femoral neck with surrounding sclerosis.

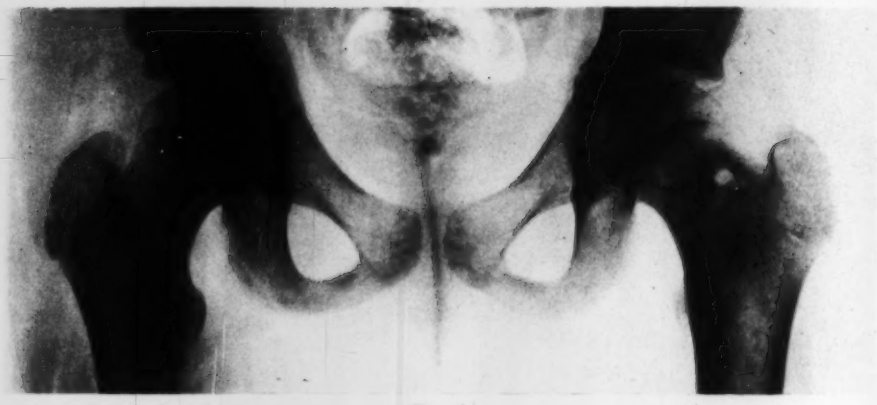


FIG. 6

Case 3—Ten months later. The lesion is clearly shown and there is osteoporosis about the left hip.

FIG. 7

Case 3—Nine months after excision of osteoid osteoma. The density of the bones has returned to nearly normal.

FIG. 8

Case 4—Initial radiograph two years after onset showing osteoporosis about the right hip and a cortical reaction in the shaft of the femur.

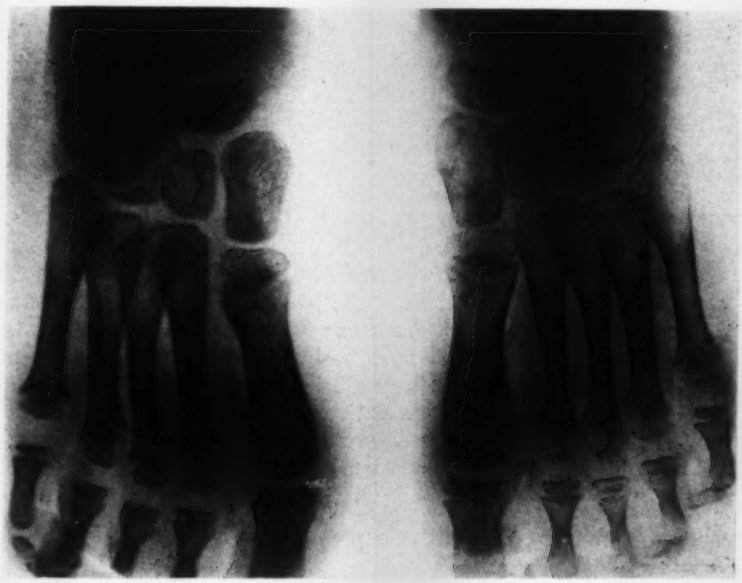


FIG. 9

Case 5—Initial radiograph showing generalised osteoporosis of the left mid-foot and a dense area in the lateral cuneiform thought to be an abscess containing a sequestrum.

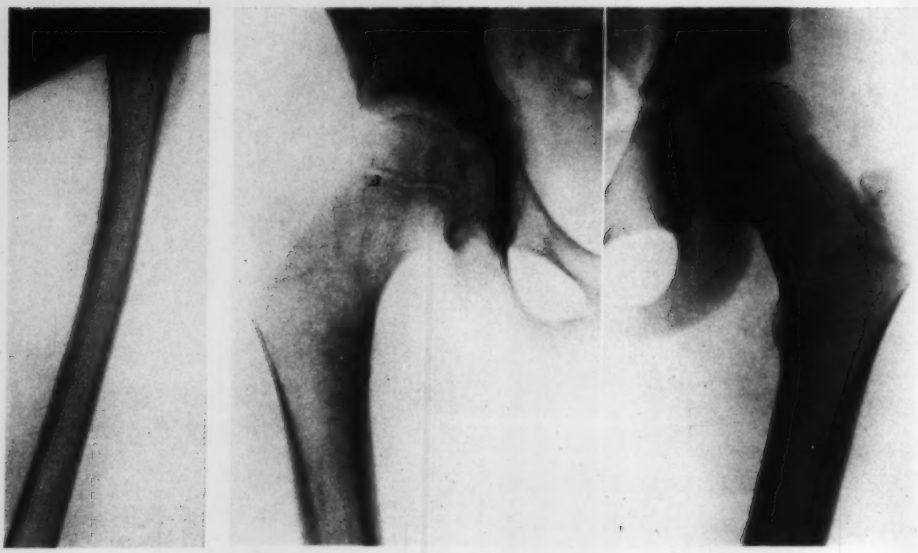


FIG. 10

Case 6—Initial radiographs showing osteoporosis of the right femur. The periosteal new bone on the anterior aspect of the upper femoral shaft was not noticed at the time.

Case 6—A girl of six was seen in September 1959 with pain in the right knee radiating to the hip and shin for five weeks. The pain was worse at nights and her mother said that she walked in an odd way, throwing the right leg out. Examination showed full hip movements and no limp, but the right buttock was wasted and the right thigh was an inch less in circumference than the left. A radiograph showed marked osteoporosis of the right femur (Fig. 10) but the periosteal new bone formation later found on the anterior aspect of the upper shaft was not noticed. The same month a full blood count was within normal limits and the Mantoux test was negative.

FIG. 11

Case 6—Five months later, showing periosteal new bone surrounding a nidus near the lesser trochanter.

Because of the persistence of pain she was admitted to hospital in February 1960 and a radiograph then showed a periosteal reaction on the antero-medial side of the femoral shaft at the level of the lesser trochanter, with a nidus (Fig. 11).

At operation a block of bone was removed containing a bright red nodule of soft tissue which on examination proved to be an osteoid osteoma.

Nine months after operation a radiograph showed a return to normal density of the bones about the right hip joint.

SUMMARY AND CONCLUSIONS

1. Regional osteoporosis is a common finding in osteoid osteoma. It may in fact be a constant feature because it was present in all the patients reported in this

paper and was suspected in others who have not been included in this report because of insufficient information.

2. Five of our six cases showed osteoporosis about the hip. Osteoporosis is more likely to be noticed in this region than in other parts of the extremities because both hips are usually radiographed on one film. We have seen several instances in which we suspected generalised osteoporosis of an extremity but Case 5 was the only one in which comparable radiographs had been taken of both feet.

3. When there is osteoporosis in the region of a joint with symptoms referred to that joint an osteoid osteoma may be the cause. The nidus may lie at some distance from the joint surfaces and may not be seen in standard radiographs of the joint (Case 4). Additional radiographs including a wider area than usual may be necessary to show the lesion, and tomography is sometimes required.

We wish to thank Mr H. J. Seddon for his assistance with this paper. Mr K. I. Nissen kindly gave permission to report Case 1 and Mr D. Trevor Case 2.

The Department of Medical Illustration, the Hospital for Sick Children, Great Ormond Street, and the Medical Photographic Department, the Institute of Orthopaedics, were responsible for the illustrations.

REFERENCES

DAVISON, W. R. (1956): Osteoid Osteoma; Report of Atypical Cases. *Clinical Orthopaedics*, **7**, 113.

DOCKERTY, M. B., GHORMLEY, R. K., and JACKSON, A. E. (1951): Osteoid Osteoma. *Annals of Surgery*, **133**, 77.

FLAHERTY, R. A., PUGH, D. G., and DOCKERTY, M. B. (1956): Osteoid Osteoma. *American Journal of Roentgenology*, **76**, 1,041.

GOLDTHWAIT, J. C., WANG, C. C., CASTLEMAN, B., and CALKINS, E. (1955): Case Records of the Massachusetts General Hospital: Weekly Clinico-pathological Exercises. *New England Journal of Medicine*, **253**, 701.

JOHNSON, G. F. (1955): Osteoid Osteoma of the Femoral Neck. *American Journal of Roentgenology*, **74**, 65.

MACKENZIE, W. (1947): Painful, Non-suppurative, Localised Sclerosis of the Long Bones. *Journal of Bone and Joint Surgery*, **29**, 49.

PHALEN, G. S., and PATCH, D. W. (1954): Pain in the Hip Caused by Osteoid Osteoma. *Clinical Orthopaedics*, **4**, 154.

RECURRENT DISLOCATION OF THE PATELLA

A Study of its Pathology and Treatment in 106 Knees

A. W. B. HEYWOOD, CAPE TOWN, SOUTH AFRICA

From the Liverpool Stanley Hospital, Liverpool, England

Despite the many methods of surgical treatment that have been described for the relief of recurrent dislocation of the patella, there is still no general agreement on its surgical management, and few long-term follow-up studies have been reported. The present study was undertaken to investigate the natural history of the condition, and to assess the value of some of the operations in current use, and also to assess in particular the long-term results of patellectomy and transplant of the tibial tubercle.

CLINICAL MATERIAL

Case notes were studied from hospitals in Liverpool, Warrington, Preston and Oswestry. The criteria for inclusion—adequate records and a follow-up period of at least a year—were satisfied in operations on ninety knees in seventy-six patients, and in a further sixteen knees not subjected to operation. Fifty-four patients were seen personally; the remainder were assessed from their case notes and from replies to questionnaires. The average follow-up period was seven years and the longest thirty years. The age of onset of the dislocations is shown in Figure 1.

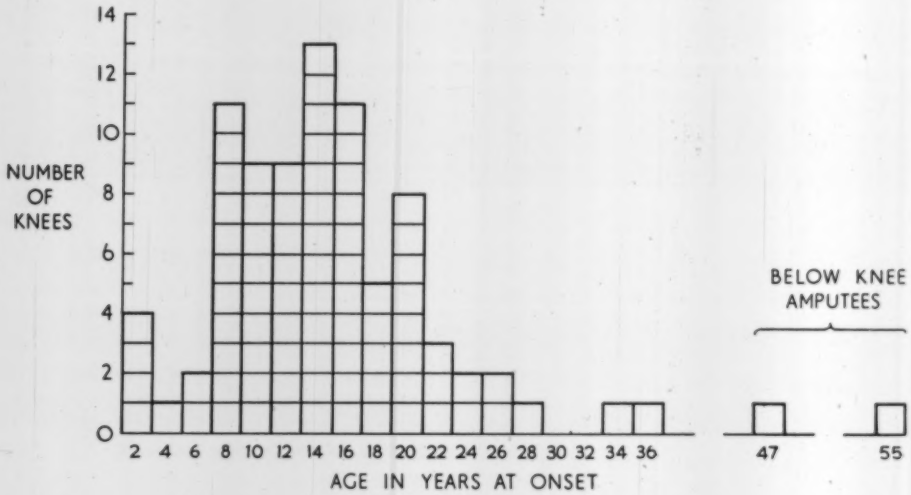


FIG. 1

The age of onset of recurrent dislocation of the patella in this series.

ETIOLOGY

Injury—In only five patients (5 per cent) could a major accident be considered the cause of recurrent dislocation. In the remainder the initial dislocation was precipitated by a trivial twist in a congenitally abnormal knee.

Below-knee amputation—Two patients developed recurrent dislocations of the patella after otherwise satisfactory below-knee amputations done twenty-two and thirty-five years previously. Since the patients were forty-seven and fifty-five years old when the dislocations started, it is assumed that the abnormal mechanics of walking with a prosthesis were responsible. This complication of below-knee amputation has not been reported previously.

The congenital diathesis—The various factors comprising the congenital diathesis have been well documented; of these, genu valgum, tibial torsion and ligamentous laxity need further elaboration.

Genu valgum—When genu valgum is found in association with recurrent dislocation of the patella it is an incidental finding and not the cause of the recurrent dislocations. Supracondylar femoral osteotomy failed to stop the recurrent dislocations in five out of seven patients in this series; and it is common knowledge that very few children with knock-knees also have recurrent dislocation of the patella.

Lateral rotational deformity of the tibia—This was noted in two children. In one, the deformities and the dislocations were bilateral. In the other, it was present only on the side on which the dislocation occurred, and limitation of lateral rotation of the hip suggested that the tibial torsion was compensatory to anteversion of the femoral neck. In these children the considerable lateral displacement of the insertion of the patellar ligament must have had some bearing on the recurrent dislocation, though this could not have occurred without laxity of the medial joint capsule as well.

TABLE I

LIGAMENTOUS LAXITY ASSOCIATED WITH RECURRENT DISLOCATION OF THE PATELLA IN FIFTY-FOUR PATIENTS

Lateral mobility of patella—all other joints stable	30 patients
Ligamentous laxity:	
Knees only	5 patients
Knees and other joints	19 patients

Ligamentous laxity—De Palma (1954) and Carter and Sweetnam (1958) have shown the relationship between recurrent dislocation of the patella and ligamentous laxity. Sometimes generalised ligamentous laxity, as in the Ehlers-Danlos syndrome (Johnson and Falls 1949), chondro-osteo-dystrophy (Fairbank 1951), arachnodactyly and osteogenesis imperfecta, is associated with recurrent dislocation of the patella.

Table I shows the incidence of ligamentous laxity in the patients examined personally in this series. Those with the generalised condition could extend their knees and elbows to more than 185 degrees, and had lax collateral ligaments. Their thumbs and fingers could be hyperextended.

Eight patients of the series had congenital deformities of the feet which included pes cavus, hammer toes, microdactyly and vertical talus.

PATHOLOGICAL CHANGES IN THE PATELLA

In some patients the patella subluxates with each genuflexion; in others it occasionally dislocates completely. Each time it dislocates or subluxates it jumps the edge of the lateral femoral condyle, and then has to jump back again to regain its central position. Since the trauma of being dragged back over the edge is greater than that of slipping laterally, the medial facet of the patella is the first to be damaged. The pathological changes that are seen include: 1) *chondromalacia of the patella* (McFarland 1948, Macnab 1952) with degeneration and erosion

of the cartilage (Fig. 2). These changes do not usually show radiographically. Loose bodies form in a small number of knees. 2) *Osteochondritis dissecans.* 3) *Marginal osteochondral fracture* (Coleman 1948). This differs from osteochondritis dissecans in that the fragment is

TABLE II

CHANGES SEEN IN TWENTY-FIVE PATELLAE AT OPERATION FOR RECURRENT DISLOCATION

Condition	Number of knees
Chondromalacia patellae . . .	19
Osteochondritis dissecans . . .	1
Marginal osteochondral fracture . .	1
Patello-femoral arthritis . . .	2
Normal cartilage	2
Total	25

separated from the patella immediately by a severe injury. 4) *Patello-femoral arthritis*, which may develop from any of the above changes.

Chondromalacia occurs in almost all of the patellae, but osteochondritis dissecans and marginal fractures are rare (Table II).

FIG. 2

Advanced erosion of patellar cartilage, exposing an area of eburnated bone.

THE RESULT IN THE UNTREATED PATIENT

Generalised osteoarthritis of the knee—Although this series is too small to warrant statistical conclusions it does show that osteoarthritis of the knee increases if the recurrent dislocation is allowed to continue indefinitely (Table III).

Spontaneous cure—In sixteen knees (15 per cent) the symptoms ceased, never to recur, after physiotherapy had developed the quadriceps. These were all young adults, in whom the patella went through a period of dislocation about the time of skeletal maturation.

TABLE III

THE INCIDENCE OF OSTEOARTHRITIS OF THE KNEE RELATED TO THE DURATION OF THE DISLOCATION

Duration of dislocation in years . . .	0–5	6–15	16–25	Over 25
Number of knees in each group . . .	58	16	9	1
Number of knees showing osteoarthritis .	0	3	3	1
Percentage showing arthritis . . .	0	19	33	100

TABLE IV

METHOD OF GRADING RESULTS OF OPERATION FOR RECURRENT DISLOCATION OF THE PATELLA

(A) Subjective grading

Excellent: No trouble at all.

Good: Occasional pain after severe exertion, or slight weakness of the knee only when descending stairs, etc.

Fair: Persistent moderate pain; inability to walk for more than a mile without having to rest.

Poor: Recurrence of dislocations. Incapacitating pain, swelling or weakness.

(B) Objective grading

Excellent: Full movements, active and passive. No tenderness.

Good: As above, but with some synovial thickening with or without wasting of the quadriceps. Inability to stand on the affected leg with the knee semi-flexed to less than 135 degrees. Persistent laxity of the patella is acceptable provided that no subluxation occurs with knee movements.

Fair: Slight tenderness of under-surface of patella or of joint margins. Tender retropatellar crepitus. Extensor lag of more than 5 degrees.

Poor: Redislocation. Recurrent effusions. Marked tenderness. Loose bodies. Less than 90 degrees of flexion.

TABLE V

THE METHOD OF CALCULATION OF COMBINED RATING FROM THE SUBJECTIVE AND OBJECTIVE GRADINGS IN TABLE IV

Subjective	Objective: Excellent	Good	Fair	Poor	Combined rating
Excellent	0	1	2	4	0 . Excellent
Good	1	2	3	4	1 . Good
Fair	3	3	3	4	2 . Fair
Poor	4	4	4	4	3 . Poor
					4 . Failure

OPERATIVE TREATMENT

Hauser (1938) gave a comprehensive historical review of the many operations that have been tried. In this series four operations are available for study: supracondylar femoral osteotomy, plastic operations on the capsule, realignment of the tibial tubercle, and patellectomy. The results of operation were investigated in three periods: one to five years; six to ten years; and over ten years. The clinical grading was done from the patient's own

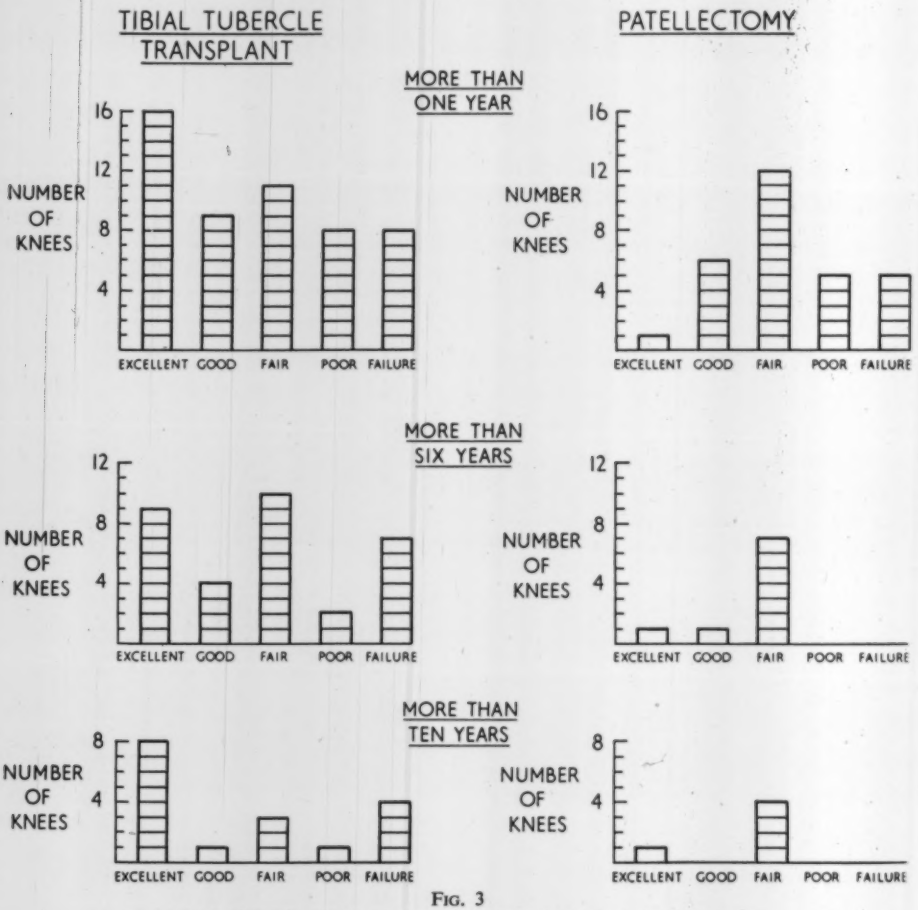


FIG. 3

Analysis of results of transplant of the tibial tubercle and of patellectomy.

account (subjective), and from the physical findings (objective) along lines similar to those used by Macnab (1952). Table IV sets out the criteria used for grading. By plotting the subjective against the objective findings in Table V a combined rating on a five-point scale was obtained. Radiological findings were of no help.

Supracondylar femoral osteotomy—This operation was used on seven knees in five patients suffering from genu valgum with recurrent dislocation of the patella. Five continued to dislocate in spite of an adequate correction.

Plastic operations—These were performed as the sole procedure on four knees. A strip o

medial parapatellar capsule was transferred either as a free graft (Davis 1919) or as a pedicle graft (Krogius 1904) to the lateral side. The dislocations recurred in two of the four knees.

Tibial tubercle transplant—This was performed on fifty-three knees of forty-two patients varying in age from five to forty-nine years, the average being eighteen. With minor variations, the technique followed that of Hauser (1938). After release of the lateral capsule the tubercle was moved medially and downwards, usually into an exactly fitting socket, but four knees required screws as well. In eight the medial capsule was reefed in addition, but this did not alter the results in any way. After eight weeks in a plaster back-slab, rehabilitation continued for three to six months.

Results—There was one death (in 1930) from purpura on the fifth post-operative day. Figure 3 shows the number of knees falling into each group in the various follow-up periods. Even after ten years there is a preponderance of " excellent " results. When one knee only was affected it remained the weaker one, and there was usually half to one inch of quadriceps wasting, even in the " excellent " knees. Knees graded " good " or " fair " had varying degrees of aching and tenderness after strenuous exertion.

Knees were graded " poor " or " failure " in the following circumstances. 1) *Recurrence of the dislocation* (three knees) (6 per cent). In one, the transplanted tubercle became infected and was removed, so the mechanical effect of the operation was lost. In another, the lateral capsule was not incised at the initial operation; a revision operation and ultimately a patellectomy failed to cure the dislocations. The third was not cured by transplant of the left tibial tubercle and later accepted patellectomy. 2) *Pain, swelling and tenderness* (seven knees) (15 per cent). In one, these symptoms came on slowly after operation and became worse over twelve years, in spite of the fact that the dislocations were relieved. Another, graded " poor " at five years, improved spontaneously to " good " at ten years. One improved after removal of a screw. One improved after removal of a loose body. Two were improved by patellectomy for pre-existing osteoarthritis, and another patient is awaiting patellectomy for this reason. 3) *Poor recovery of flexion* (two knees) (4 per cent). One took a year to regain flexion to 90 degrees; the other had two manipulations and a patellectomy in unsuccessful efforts to regain more than 30 degrees of flexion. Both these patients were over forty at the time of operation. 4) *Genu recurvatum* (four knees). This will be discussed later.

Ten knees (20 per cent) required a total of sixteen further operations after transplant of the tibial tubercle. These included three tibial osteotomies for recurvatum, and three patellectomies: one had a tender neuroma excised; one had a screw removed for low-grade sepsis; three had transplanted tibial tubercles drilled or trimmed for pain; and one had a loose body removed.

Tibial tubercle transplant in children—Macnab (1952) and Harrison (1955) emphasised the danger of this operation before fusion of the epiphyses. In this series the tibial tubercle was transplanted in thirteen knees in children under fourteen. In one the operation failed to cure the recurrent dislocations; four knees developed recurvatum deformity, two of these with severe valgus, requiring tibial osteotomy. The remainder gave good results.

Genu recurvatum may be caused by epiphysiodesis, which is liable to occur if the block of bone removed with the tubercle damages the upper tibial epiphysis, and especially if the cavity left by the removal of the tibial tubercle is filled by the piece of bone taken from its new bed (Figs. 4 to 6). Another cause is downward migration of the tibial tubercle; if the ligamentum patellae alone is removed, with or without a sliver of bone, the epiphysial line may escape damage, but being transferred from its epiphysial insertion into the metaphysis, it migrates downward with growth. Pulling the patella down too far causes chondromalacia (Macnab 1952) and recurvatum (Harrison 1955) because of the excessive tightness of the extensor mechanism.

Tibial tubercle transplant in older adults—The best results were obtained when the operation was performed between the ages of fifteen and thirty years; in older patients the results were spoiled by persistent pain and stiffness.

FIG. 4

FIG. 5

FIG. 6

Severe genu valgum and recurvatum caused by antero-lateral epiphysial arrest from tibial tubercle transplant. Figure 4 shows that part of the epiphysial plate has been removed and has been replaced by the bone taken from the new bed for the tubercle. Figure 5 shows that solid epiphysiodesis has occurred nine months later. Figure 6 shows that, after five years, there is severe tilting of the tibial table.

Patellectomy—This operation was performed on twenty-nine knees in twenty-four patients aged from fourteen to sixty-five years, with an average of twenty-nine. Five knees were osteoarthritic.

There was a variation in the technique of the operation in dealing with the quadriceps expansion. To prevent recurrent dislocation of the " patella substitute " which may form at the site of the excised patella, McFarland (1948, 1959) advised a Krogius (1904) type of capsulorrhaphy, a strip of medial capsule being transferred to the lateral side. This was done in some patients, others were repaired in the usual transverse manner, and some had no repair at all (Table VI).

After patellectomy there was usually a delay of about two years before the final stage of recovery was reached, with a 5–10 degree extensor lag until that time.

Results—Figure 3 shows the numbers of knees falling into each grade in the various post-operative periods. The average result after each operation was " fair," with a combined rating of 1·6 to 2·2.

The usual disability in " fair " and " good " results after patellectomy was a variable degree of extensor weakness associated, as after tibial tubercle transplant, with half to one inch of quadriceps wasting. Three of these knees were mildly painful with joint line tenderness related to change in the weather. The five osteoarthritic knees were relieved of patellar pain, even after ten years.

TABLE VI

VARIATIONS IN TECHNIQUE OF PATELLECTOMY

Procedure	Number of operations
Simple excision	6
Excision and quadriceps repair . .	12
Excision and capsulorrhaphy . .	10
Excision and tibial tubercle transplant	1
Total	29

Knees were graded "poor" or "failure" after patellectomy in the following circumstances. 1) *Recurrent dislocation of the " patella substitute "* (two knees) (7 per cent); in neither was capsulorrhaphy done at the time of operation, and both were later relieved by tibial tubercle transplant. 2) *Pain, swelling and tenderness* (three knees) (10 per cent); in one no reason could be found; the other two had generalised osteoarthritis before operation. 3) *Poor recovery of flexion* (two knees) (7 per cent), in both of which a capsulorrhaphy had been done. One patient, aged thirty-eight, regained 90 degrees of flexion after manipulation, but the other, aged twenty-seven, did not. 4) *Extensor lag over* 10 *degrees with severe weakness* (three knees) (10 per cent). Two of these knees were osteoarthritic and all three are still improving two to three years after operation.

These findings were encountered in the first five-year period after operation. Most knees seen more than five years after operation were " fair "; this is in accord with the findings of Scott (1949) and Smillie (1951), who emphasised that a knee without its patella is partly disabled.

DISCUSSION

Most authorities have favoured one or other of the two principal operations reviewed in this survey (McFarland 1948, Smillie 1951, 1959, Harrison 1955, West and Soto-Hall 1958), though Macnab (1952) advised inspection of the deep surface of the patella before deciding which operation to do. From the material available in the present series it is possible to learn something more about the selection of patients for operation.

Degeneration of the patellar articular cartilage is usually present by the time the patient comes to operation. If left untreated for many years this process is liable to culminate in generalised osteoarthritis of the knee. It is essential to decide whether a realignment procedure will prevent this progressive degeneration, because if not there is no place for the operation. The fact that transplant of the tibial tubercle can give a majority of " good " and " excellent " results in a five to thirty year follow-up supports the contention of Harrison (1955) and Smillie (1959) that the degeneration will stop after adequate realignment. This only obtains when the operation is performed with meticulous attention to detail in adolescents and young adults who have not yet developed patello-femoral arthritis.

In transplanting the tubercle a lateral release of the quadriceps expansion should be done to allow the tubercle to swing medially and downwards to obtain a secure fit without the use of a screw.

Below the age of fourteen years four out of thirteen children developed genu recurvatum after transplant of the tibial tubercle to the metaphysis, even when the epiphysis was not disturbed. The operation is therefore contra-indicated in any form in children, as was stressed by Macnab (1952) and Harrison (1955). This study does not provide a useful alternative: supracondylar femoral osteotomy and plastic operations on the lateral quadriceps expansion were unsuccessful, and no example of patellectomy could be traced in this age group. However, when conservative measures fail, surgery may be indicated to prevent further articular damage. There is a reluctance to remove the patella in children on the grounds that its absence renders the knee more susceptible to the injuries of childhood, and that the quadriceps expansion may rupture from attrition. These objections are not sound, because repeated dislocations are more damaging than is the absence of the patella; and no rupture from attrition occurred in this series. If patellectomy is performed it must be accompanied by plastic rerouting. In children the situation is not satisfactory, and more work is required in this field.

Over the age of thirty an increasing number of tibial tubercle transplants do badly. In these patients patellectomy should be considered more frequently, and over forty patellectomy is the operation of choice. At any age pain with retropatellar tenderness, crepitus and a thickened, tender synovium may be caused by patello-femoral arthritis, and the articular surfaces should be opened for inspection at operation. A circumscribed area of erosion on the under-surface of the patella does not contra-indicate tibial tubercle transplant, but a more extensive denudation of the bony surfaces does, in which case the patella should be removed.

Patellectomy was found to be a sound operation in this series. While yielding but few excellent results, it can generally be relied upon to give a fair result with little risk of failure; it should be done when tibial tubercle transplant is contra-indicated by any of the above reasons. Recurrent dislocation of the " patella substitute " after patellectomy must be prevented at the time of operation by rerouting the quadriceps mechanism either by a plastic procedure or by tibial tubercle transplant.

In patients in whom the patella is permanently dislocated—the so-called congenital type—realignment is unsuccessful. There is no jumping of the condylar ridge, so the disability may not be severe. If surgery becomes inevitable, simple patellectomy is the best procedure, without any attempt at rerouting the quadriceps mechanism. The same holds good when the dislocation is caused by the muscular imbalance after poliomyelitis or in spastic paraplegia, in which intermittent dislocations may become permanent in the course of time.

SUMMARY

1. A study has been made of the treatment of recurrent dislocation of the patella in 106 knees in seventy-six patients.

2. In young adults in whom degenerative changes in the knee were not severe at the time of operation transplant of the tibial tubercle gave the best results.

3. In older patients and in those in whom osteoarthritic changes were present in the knee transplant of the tibial tubercle was unsatisfactory, but patellectomy with rerouting of the quadriceps mechanism gave fair results.
4. Tibial tubercle transplant is contra-indicated in children because it may give a recurvatum deformity.
5. When the dislocation is permanent, operation may be unnecessary, but if it becomes inevitable simple patellectomy is the best procedure.
6. The results of plastic operations on the quadriceps expansion and of supracondylar femoral osteotomy are bad.
7. No operation can give consistently good results because the knee is usually congenitally weak, often as part of generalised ligamentous laxity.

I would like to express my sincere thanks to the consultant staff of the following hospitals for allowing me access to their records and patients: the Liverpool Royal Infirmary, the Royal Southern Hospital, the David Lewis Northern Hospital, the Alder Hey Hospital, the Robert Jones and Agnes Hunt Orthopaedic Hospital, Oswestry, the Birkenhead General Hospital, the Preston Royal Infirmary, the Warrington Infirmary and the Bootle Hospital.

I am especially grateful to Professor Bryan McFarland, Mr Norman Roberts and Mr Goronwy E. Thomas for their encouragement and for their criticism of this paper.

REFERENCES

CARTER, C., and SWEETNAM, R. (1958): Familial Joint Laxity and Recurrent Dislocation of the Patella. *Journal of Bone and Joint Surgery*, **40–B**, 664.

COLEMAN, H. M. (1948): Recurrent Osteochondral Fracture of the Patella. *Journal of Bone and Joint Surgery*, **30–B**, 153.

DAVIS, C. B. (1919): Recurrent Dislocation of the Patella. *Surgical Clinics of North America*, **3**, 291.

DE PALMA, A. F (1954): *Diseases of the Knee*. Philadelphia, London, Montreal: J. B. Lippincott Company.

FAIRBANK, Sir T. (1951): *An Atlas of General Affections of the Skeleton*, p. 125. Edinburgh and London: E. & S. Livingstone Ltd.

GOLDTHWAIT, J. E. (1904): Slipping or Recurrent Dislocation of the Patella. *Boston Medical and Surgical Journal*, **150**, 169.

HARRISON, M. H. M. (1955): The Results of a Realignment Operation for Recurrent Dislocation of the Patella. *Journal of Bone and Joint Surgery*, **37–B**, 559.

HAUSER, E. D. W. (1938): Total Tendon Transplant for Slipping Patella. *Surgery, Gynecology and Obstetrics*, **66**, 199.

JOHNSON, S. A. M., and FALLS, H. F. (1949): Ehlers-Danlos Syndrome. *Archives of Dermatology and Syphilology*, **60**, 82.

KAPLAN, E. B. (1957): Factors Responsible for the Stability of the Knee Joint. *Bulletin of the Hospital for Joint Diseases*, **18**, 51.

KROGIUS, A. (1904): Zur operativen Behandlung der habituellen Luxation der Kniescheibe. *Zentralblatt für Chirurgie*, **31**, 254.

MCCARROLL, H. R., and SCHWARTZMANN, J. R. (1945): Lateral Dislocation of the Patella. Correction by Simultaneous Transplantation of the Tibial Tubercle and Semitendinosus Tendon. *Journal of Bone and Joint Surgery*, **27**, 446.

MCFARLAND, B. (1948): Excision of Patella for Recurrent Dislocation. *Journal of Bone and Joint Surgery*, **30–B**, 158.

MCFARLAND, B. (1959): *Personal communication.*

MACNAB, I. (1952): Recurrent Dislocation of the Patella. *Journal of Bone and Joint Surgery*, **34–A**, 957.

SCOTT, J. C. (1949): Fractures of the Patella. *Journal of Bone and Joint Surgery*, **31–B**, 76.

SMILLIE, I. S. (1951): *Injuries of the Knee Joint*. Edinburgh: E. & S. Livingstone Ltd.

SMILLIE, I. S. (1959): Ligamentous Injury and Subluxation of the Patella. *Journal of Bone and Joint Surgery*, **41–B**, 214.

WEST, F. E., and SOTO-HALL, R. (1958): Recurrent Dislocation of the Patella in the Adult. End Results of Patellectomy with Quadricepsplasty. *Journal of Bone and Joint Surgery*, **40–A**, 386.

INNOMINATE OSTEOTOMY IN THE TREATMENT OF CONGENITAL DISLOCATION AND SUBLUXATION OF THE HIP*

ROBERT B. SALTER, TORONTO, CANADA

From the Department of Surgery, University of Toronto, and the Hospital for Sick Children, Toronto

The purpose of this paper is to describe a method of overcoming the instability of reduction in congenital dislocation and subluxation of the hip in children over the age of eighteen months. Despite the emphasis on early diagnosis and treatment, and although there is a great increase in the number of infants referred early, a disturbing number of children still remain undiagnosed until some time after they have learned to walk. It is with this group, over the age of eighteen months, that the present paper is concerned.

Throughout this paper a distinction will be made between congenital dislocation and congenital subluxation. During the first few months of life a subluxation of the hip may either become a dislocation or remain a subluxation; by eighteen months, however, an untreated hip that is still subluxated is likely to remain as a subluxation. In the age group under consideration the two conditions exhibit certain differences in their pathology which must be taken into consideration during treatment.

THE PROBLEM OF INSTABILITY OF REDUCTION

Initial reduction of the congenital dislocation between the ages of eighteen months and six years can usually be obtained by a period of traction followed by either closed or open reduction. In congenital subluxation, on the other hand, reduction occurs with simple abduction and flexion of the hip. The main problem is not the reduction but the instability of reduction in both congenital dislocation and congenital subluxation. The reduced hip is stable in a position of abduction, flexion and varying degrees of rotation; however, the hip is unstable and either redislocates or resubluxates when the limb is brought back into the functional position of walking.

During the first twelve months of life the problem of instability of the reduced hip can usually be overcome by maintaining the hip in a stable position for a period of a relatively few months. During this period normal—or nearly normal—osseous development of the cartilage model of the acetabulum and femoral head can be expected to take place; consequently the reduced hip eventually becomes stable even in the functional position of walking. This potential for normal osseous development after reduction of the dislocation or subluxation is greatest at birth and gradually decreases thereafter; by contrast, as long as the hip remains unreduced, the secondary changes—which are minimal at birth—become progressively more marked. Because of the combination of these two factors, the possibility of reversing these secondary changes diminishes fairly rapidly. Indeed, by about eighteen months of age, normal osseous development of the acetabulum and femoral head is no longer assured even by prolonged retention of the reduced hip in a stable position.

If treatment of congenital dislocation or congenital subluxation has not stimulated adequate osseous development the hip is seldom stable in the functional position of walking. Furthermore, once weight bearing is allowed normal osseous development of the acetabulum and femoral head can continue only if the reduction remains completely stable. Even a slight residual or recurrent subluxation gradually becomes worse with weight bearing, with the result that further osseous development is imperfect and there ensues a gradual deterioration

* Read at the Annual Meeting of the Canadian Orthopaedic Association, Waskesiu, June 1960, and also summarised at the eighth Congress of the International Society of Orthopaedic Surgery and Traumatology, New York, 1960.

of the function of the hip. This unfavourable sequence of events is readily seen by studying the consecutive radiographs of a large number of patients in whom treatment was instituted after the age of eighteen months.

EXISTING METHODS OF OVERCOMING THE INSTABILITY OF REDUCTION

Many and varied are the methods of treatment designed to provide stability of the reduced congenital dislocation and congenital subluxation in children over the age of eighteen months. These methods may be considered in three main groups, any of which may be combined: prolonged retention of reduction in a stable position, operations on the femur, and operations on the pelvis.

Prolonged retention of reduction in a stable position—This method, effective in infants during the first twelve months of life, gradually becomes less effective, especially after eighteen months of age, even with prolonged treatment. Prolonged immobilisation of the hip in this latter age group is usually accompanied by considerable joint stiffness, contracture, atrophy of muscles and osteoporosis; furthermore, immobilisation provides little stimulus for osseous development of the acetabulum (Hass 1951). The type of retention that allows movement of the hip within a restricted range provides a better stimulus for osseous development of the acetabulum than does immobilisation (Ponseti 1944, Schwartz 1945, Compere and Schnute 1946), but even this is often inadequate in the older child. The author suspects that retention of reduction by maintaining the hip in full medial rotation for several months or more actually produces medial femoral torsion which, in effect, amounts to increasing the degree of anteversion of the femoral neck.*

The percentage of unsatisfactory results from prolonged immobilisation of the reduced hip in children over the age of eighteen months has stimulated many orthopaedic surgeons to adopt a more direct approach to the problem (Galloway 1920, Groves 1928, Farrell and Howorth 1935, Crego and Schwartzmann 1948, Somerville 1953, Somerville and Scott 1957, Trevor 1957).

Operations on the femur. *Lateral rotation osteotomy*—The role of femoral anteversion in congenital dislocation or subluxation of the hip is controversial (Badgley 1949, Hass 1951). The author agrees with Shands and Steele (1958) that if concentric reduction can be maintained while the child is walking, anteversion usually corrects spontaneously in time. Although lateral rotation osteotomy as advocated by Crego and Schwartzmann (1948), Platou (1953*a*), Somerville (1953) and Trevor (1958) is effective in directing the femoral head into the acetabulum and preventing anterior subluxation, it does not always prevent upward and lateral subluxation because it does not ensure satisfactory coverage of the femoral head. Furthermore, if the hip has not been made stable by the rotation osteotomy the anteversion recurs, necessitating a second rotation osteotomy.

Adduction osteotomy—Valgus deformity of the femoral neck in these patients is often more apparent than real because of anteversion of the femoral neck. Nevertheless true valgus deformity does occur occasionally. In such a case subtrochanteric adduction osteotomy improves the stability of the hip by placing the femoral neck in abduction relative to the acetabulum (Pauwels 1951). This operation has the disadvantage of producing considerable shortening of the limb; furthermore, the ilium-to-trochanter distance is decreased and the efficiency of the abductor muscle group is thereby diminished. It is significant that often the surgically produced varus gradually straightens out over the ensuing few years, even to the extent of returning to a valgus deformity. Combined adduction and lateral rotation osteotomy has been performed by some surgeons (Somerville and Scott 1957, Trevor 1958) in an attempt to improve the result derived from lateral rotation osteotomy alone.

Operations on the pelvis—Various operative procedures have been performed on the pelvis to provide stability of the reduced congenital dislocation and congenital subluxation. Their

* This phenomenon is at present being investigated in growing rabbits.

terminology is somewhat confusing but they conform to three main types: the shelf operation, acetabuloplasty and capsular arthroplasty.

Shelf operation—In this paper the term shelf operation will mean the construction of an extra-articular bony buttress extending beyond the joint margin without alteration of the slope of the acetabulum (Gill 1935, Dickson 1935, Bosworth, Fielding, Liebler, Ishizuka, Ikeuchi and Cohen 1960). The buttress, if placed close to the joint margin and directed downward, laterally and parallel to the neck of the femur, reinforces the fibrous capsule of the joint and prevents lateral and upward subluxation. The osseous development of the acetabulum may or may not improve but the hip usually remains stable. Often the buttress is placed in an incorrect position; because it then serves no useful purpose it gradually disappears (Ponseti 1946). The type of bony buttress constructed over a completely dislocated femoral head is irrelevant to this discussion.

Chiari (1955) and Kawamura (1959) described another method of providing an extra-articular bony buttress. After complete osteotomy of the pelvis above the acetabulum, the distal segment containing the hip joint is shifted medially. The cut surface of the proximal segment then lies directly above the medially displaced femoral head, thereby preventing subsequent upward subluxation. The main source of concern about this operation is the resultant decrease in the capacity of the bony pelvis which, in females, could well present obstetrical difficulties in adult life. The author has had no experience with this procedure.

Acetabuloplasty—An operation designed to change the slope of the roof of the acetabulum by an incomplete osteotomy above the joint and insertion of a bone graft to keep the osteotomy site open, will be referred to in this paper as acetabuloplasty (Albee 1915, Crego and Schwartzmann 1948, Wiberg 1953). In 1934 McDonald, in an attempt to obtain better coverage of the femoral head, began to perform an extensive type of acetabuloplasty which he called " depression of the roof of the acetabulum "; the osteotomy extended inwards to, and occasionally through, the inner cortex of the ilium and the depression of the acetabular roof was maintained by beef bone wedges. Pemberton (1958), recognising the importance of preventing redislocation anteriorly, devised a more extensive type of acetabuloplasty which he called osteotomy of the ilium with rotation of the acetabular roof. The osteotomy extends through the inner cortex of the ilium but not into the sciatic notch, and the iliac portion of the acetabulum is hinged forward on the triradiate cartilage.

Line drawings of the various types of acetabuloplasty tend to be misleading because they usually show a perfectly smooth contour of the acetabulum after operation; but, as can be readily demonstrated in the cadaver, it is not possible to change the slope of only the iliac part of the socket without producing an angulation of the articular surface and a triangular shape of the rim of the acetabulum. Because of this, the internal congruity of the joint is altered and degenerative changes in the joint may be expected later. Also, it can be shown that the capacity of the acetabulum is decreased by acetabuloplasty; prising the acetabular roof down against the femoral head produces excessive and continuous compression of the opposing joint surfaces during the post-operative period of immobilisation and may result in pressure necrosis of articular cartilage (Salter and Field 1960).

Capsular arthroplasty—Colonna (1936, 1953) provided stability of reduction by creating a deep bony socket either at the site of the original acetabulum or slightly higher, and employed the redundant joint capsule as an interposition membrane on the principle of an arthroplasty. This procedure seems best suited for older children in whom it has not been possible to reduce the femoral head with impunity into the original acetabulum even after prolonged skeletal traction.

RESULTS OF EXISTING METHODS OF TREATMENT

It is well recognised that many excellent results have been obtained in children over the age of eighteen months with previously untreated congenital dislocation and subluxation of the hip by one or more of the aforementioned methods of treatment. Nevertheless, in

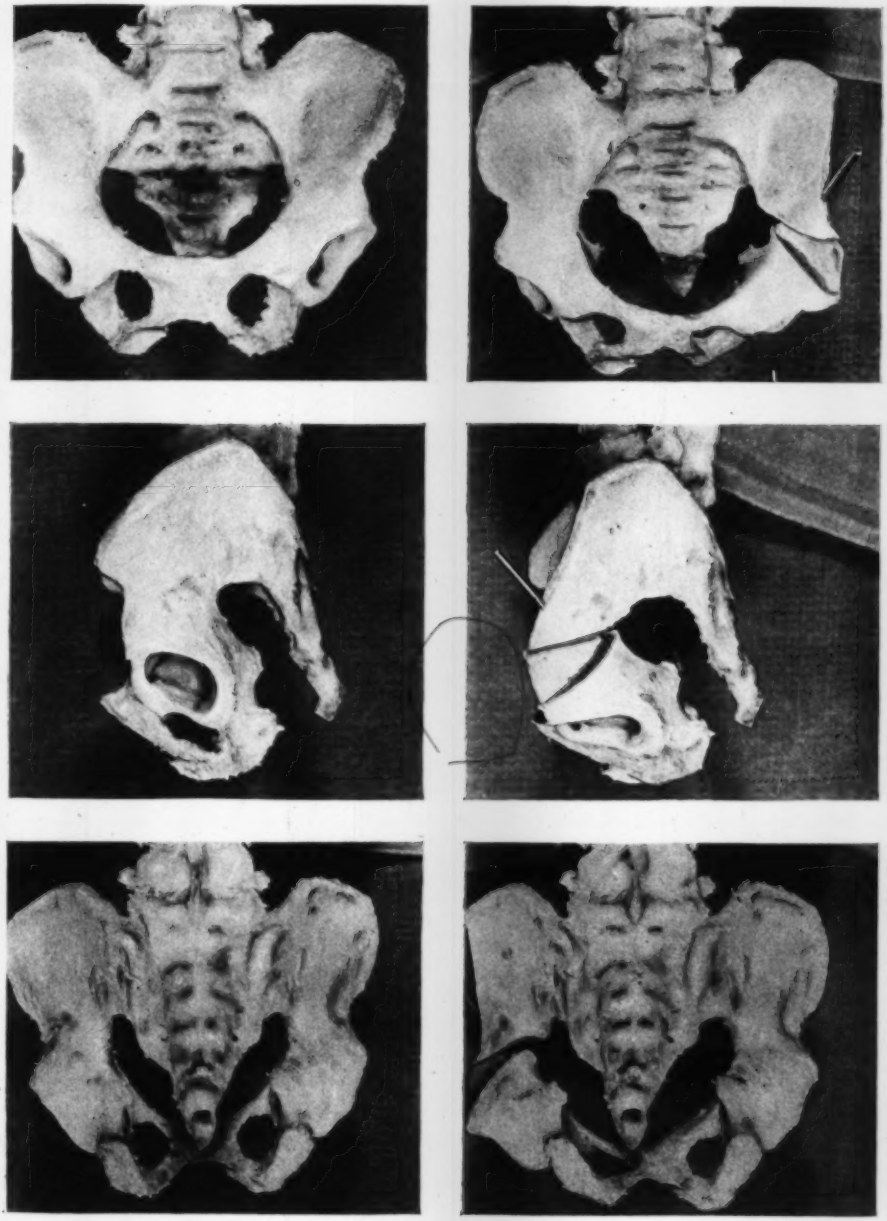


FIG. 1

FIG. 2

Dissected pelvis of a two and a half-year-old girl. Figure 1—Natural state. Figure 2—An osteotomy through the left innominate bone has been done to demonstrate the redirection of the entire acetabulum.

the many well documented follow-up studies published the percentage of excellent results is not so high that the search for more effective methods of treating this difficult condition should cease (Gill 1948, Crego and Schwartzmann 1948, Leveuf 1948, Massie and Howorth 1951, Hass 1951, Muller and Seddon 1953, Platou 1953*b*, Platt 1956, Trevor 1957, Ponseti and Frigerio 1959, Esteve 1960, Wilkinson and Carter 1960, MacKenzie, Seddon and Trevor 1960).

THE BASIC CAUSE OF INSTABILITY AFTER REDUCTION

Dissatisfaction with the results of existing methods of treatment in the child over the age of eighteen months has stimulated the author to study the basic cause of instability after reduction. The direction in which the acetabulum faces in a congenitally dislocated hip merits consideration. Langenskiöld (1953) and Laurent (1953) described a "frontal inclination" of the acetabulum, which faces in a more anterior and a less lateral direction than normal.

Radiographs fail to provide a three-dimensional concept of the acetabulum. The usual antero-posterior and "frog" positions give two views of the femora but only one of the pelvis. Oblique views of the pelvis are useful but a lateral view of the acetabulum is unsatisfactory. Only at open operation can one obtain a three-dimensional concept of the abnormality of the acetabulum in congenital dislocation of the hip, and the author has repeatedly made the observation that there is much more than a defect in the roof of the acetabulum. Indeed, the entire acetabulum, rather than facing downwards, is directed antero-laterally more than is normal, so that the femoral head is inadequately covered anteriorly when the hip is extended and laterally when the hip is adducted. This observation explains why the reduced hip is stable in a position of abduction and flexion and why it redislocates or resubluxates laterally in a position of adduction and anteriorly in a position of extension. This observation also explains why, in the presence of excessive anteversion of the femur, the combination of lateral rotation and extension results in anterior redislocation or resubluxation. In the author's opinion the basic abnormality responsible for instability of the reduced congenital dislocation is the abnormal direction in which the entire acetabulum faces.

THE DESIGN AND PRINCIPLE OF INNOMINATE OSTEOTOMY

From the foregoing observations it seemed reasonable that if the entire acetabulum could be made to face in a normal direction the reduced hip would be stable in the position of function. Consequently, an operation has been designed to redirect the entire acetabulum as one piece. Studies on the cadaver revealed that if the innominate bone was completely divided transversely just above the hip joint the acetabulum, being contained in the distal segment, could be redirected in a satisfactory manner by opening the osteotomy site antero-laterally (Figs. 1 and 2). These studies also demonstrated conclusively that all three components of the acetabulum (ilium, pubis and ischium) remained as a unit and that the distal segment of the innominate bone definitely changed direction by a combination of hinging and rotation through the symphysis pubis which, in children, is quite mobile. It was also possible to demonstrate that innominate osteotomy produced neither an alteration in the shape of the acetabulum nor a decrease in its capacity (Fig. 3).

The principle of innominate osteotomy is simply redirection of the entire acetabulum in such a way that the reduced dislocation or subluxation, which previously was stable only in a position of abduction and flexion, is made stable in the position of function (Fig. 4). This allows early weight bearing which, with the stability, is an excellent stimulus for further osseous development of the components of the hip.

APPLICATION OF THE PRINCIPLE OF INNOMINATE OSTEOTOMY

The principle of innominate osteotomy is equally applicable to both congenital dislocation and congenital subluxation in the age group under consideration. Complete reduction of the

hip is an essential prerequisite for innominate osteotomy. In order to achieve absolute concentric reduction of a complete dislocation in this age group it is often necessary to open the joint at the time of operation; complete reduction of a subluxation is obtained by abducting and flexing the hip.

Congenital dislocation. *Preliminary traction*—In a child over the age of eighteen months with congenital dislocation of the hip the pelvifemoral muscles, particularly the iliopsoas, the adductors and the hamstrings, have failed to lengthen adequately. Therefore, continuous skin traction is employed before any attempt at reduction is made. The period of traction varies with the age of the child and the amount of displacement, but the average is about two weeks. *Attempt at closed reduction*—Following the period of traction, any residual adduction

FIG. 3

Radiograph of the dissected pelvis of a two and a half-year-old girl. An innominate osteotomy has been done on the right. The acetabula have been lined with barium sulphate to show that the osteotomy has produced neither an alteration in the shape of the acetabulum nor a decrease in its capacity.

contracture is overcome by subcutaneous adductor tenotomy under general anaesthesia and a gentle attempt at closed reduction is made. Arthrography is helpful at this stage in assessing the completeness of reduction. If complete reduction can be obtained without the use of force, and if the reduction is reasonably stable in a moderate degree of abduction and flexion, a plaster hip spica is applied and operation is deferred. Should subsequent osseous development of the hip be inadequate, innominate osteotomy can be performed later. In the age group under consideration complete stable reduction is not usually obtained by the closed method, and open operation is required.

Congenital subluxation of the hip—The operative treatment of congenital subluxation of the hip is exactly the same as for congenital dislocation except that the joint need not be opened.

Bilateral congenital dislocation or subluxation of the hip—Bilateral involvement may consist of bilateral dislocation, bilateral subluxation, or dislocation of one hip and subluxation of the other. The second hip is operated upon about two weeks after the first; blood transfusion is more often deemed necessary during the second operation than during the first.

TECHNIQUE OF COMBINED OPEN REDUCTION AND INNOMINATE OSTEOTOMY

The surgical approach is so designed that the combination of accurate open reduction and stabilisation of the reduction by innominate osteotomy can be performed through the same incision at one operation. Blood transfusion is not always necessary, but continuous intravenous infusion is indicated as a precautionary measure should blood be required. The patient lies supine on the operation table with a sandbag under the thorax on the affected side (Fig. 5). The draping is so arranged that the lower limb is free to be moved during the operation. Any residual contracture of the adductor muscles is dealt with by subcutaneous adductor tenotomy unless it has been done earlier.

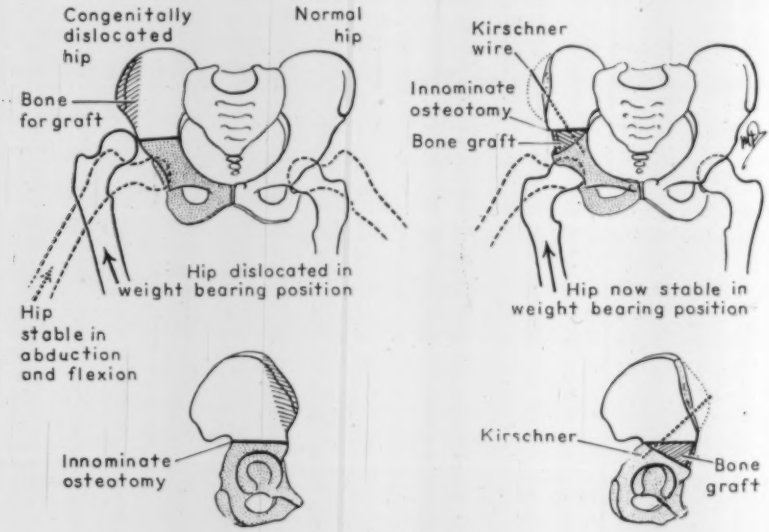
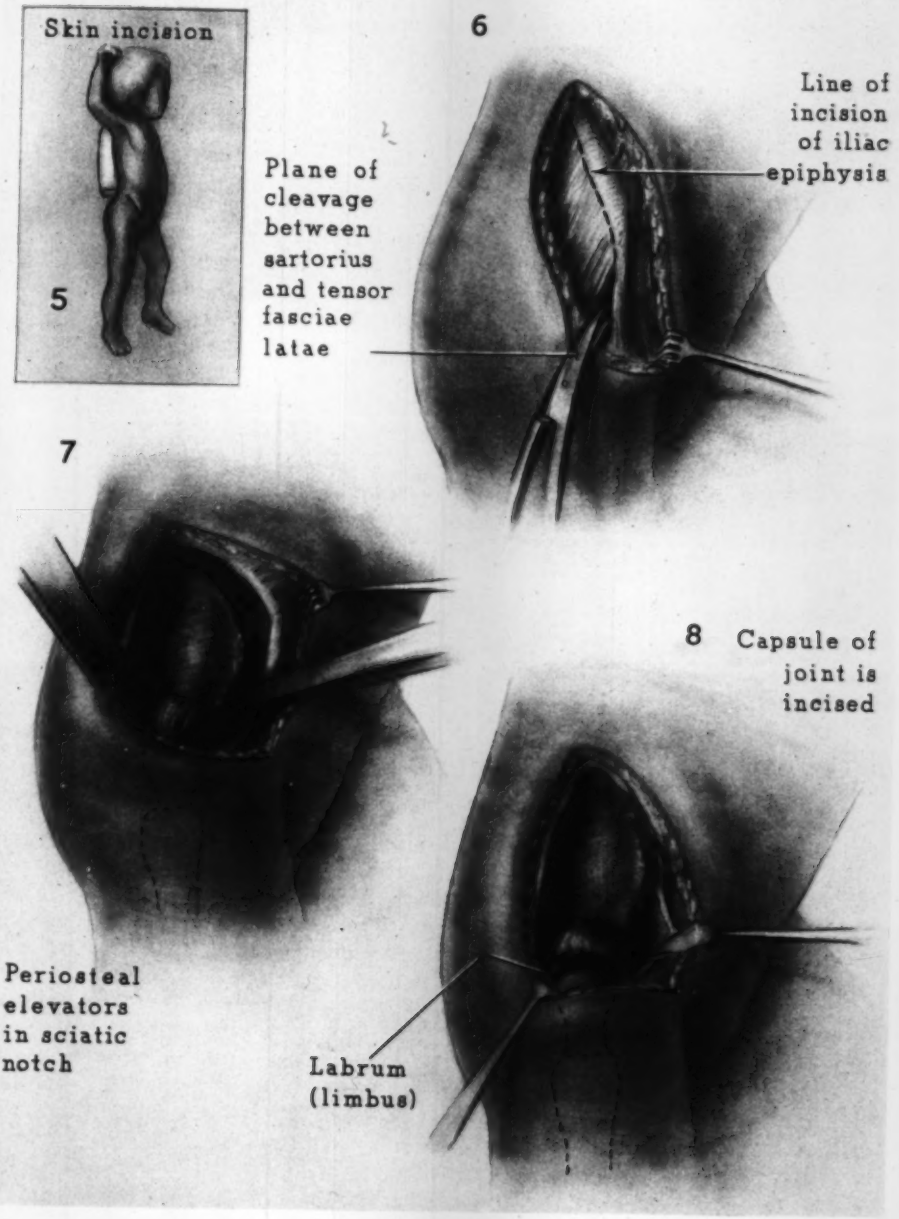


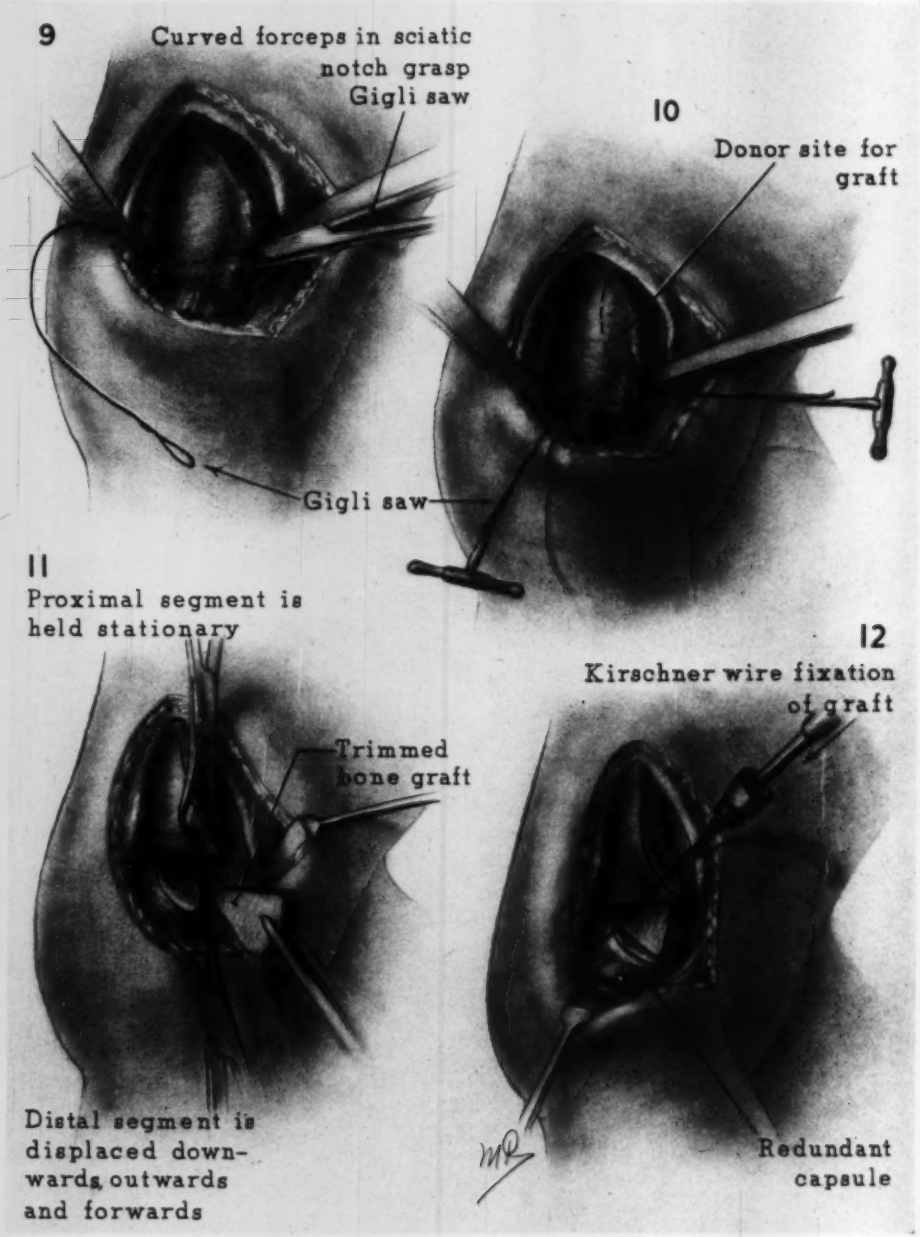
FIG. 4
The principle of innominate osteotomy.

Exposure—The skin incision begins below the middle of the iliac crest and passes obliquely forwards distal to the anterior superior spine almost to the mid point of the inguinal ligament (Fig. 5). The anterior aspect of the hip joint is exposed by dissecting between the tensor fasciae latae laterally and the sartorius and rectus femoris medially as described by Smith-Petersen (1917), after which this space is packed (Fig. 6). An incision is made in the iliac apophysis down to bone along the iliac crest from its mid-point to the anterior superior spine and then distally to the anterior inferior spine. The lateral part of the apophysis with the periosteum of the external surface of the ilium is then stripped in a continuous sheet inferiorly to the lateral edge of the acetabulum and posteriorly to the greater sciatic notch: this space is then packed. If the fibrous capsule of the hip has become adherent to the lateral aspect of the ilium above the acetabulum by being stretched upward by the intracapsular dislocation it should be freed by the use of a periosteal elevator. Blunt dissection in the plane between the fibrous capsule and abductor muscles provides excellent exposure of the anterior and lateral part of the capsule (Fig. 7).

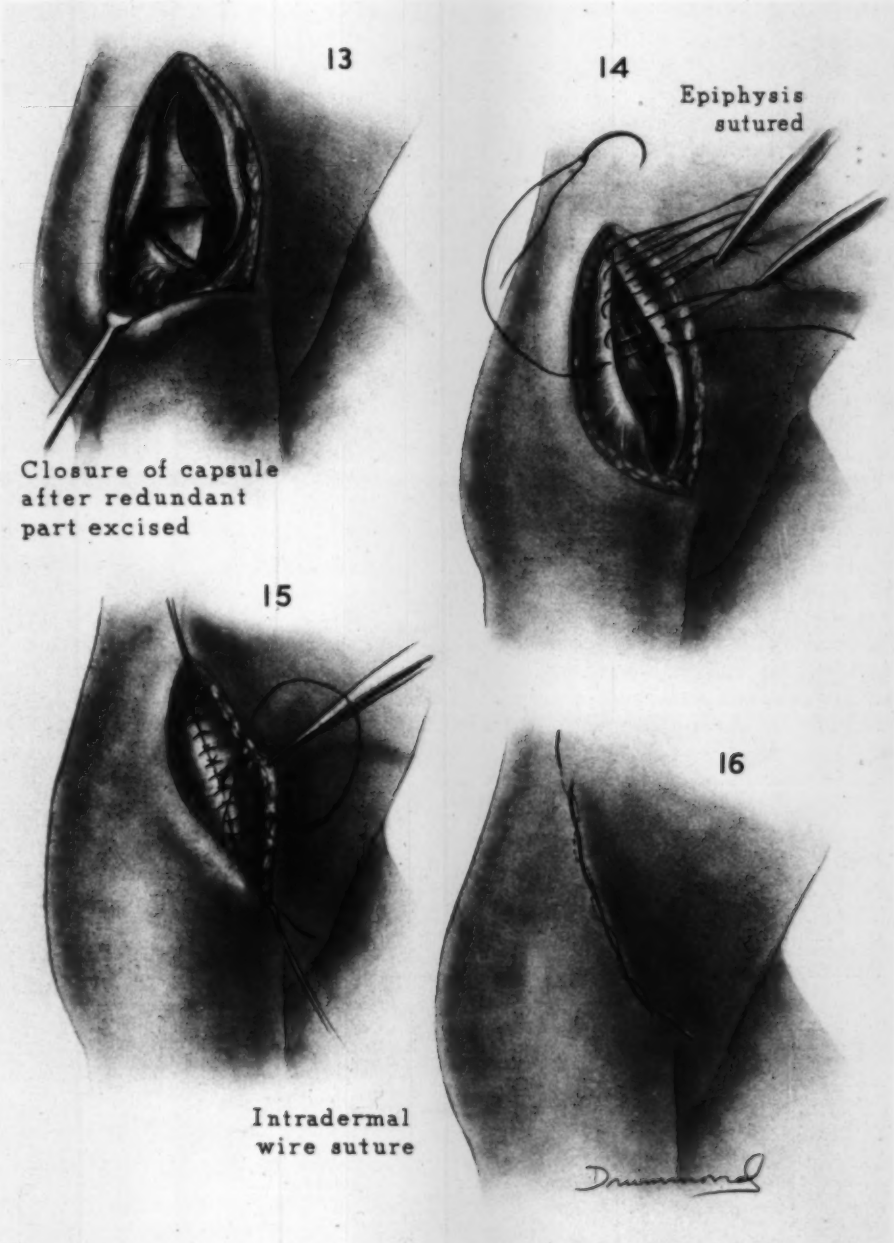
Open reduction—The capsule is opened widely close to the superior and anterior margins of the acetabulum (Fig. 8). Excessive fibro-fatty tissue in the base of the acetabulum is gently removed but the ligamentum teres is left intact unless it is grossly hypertrophied. The limbus does not obstruct reduction when the capsule is widely opened and therefore it is preserved. The abnormal direction in which the entire acetabulum faces can be appreciated at this stage.



FIGS. 5 TO 8
The technique of combined open reduction and innominate osteotomy.



FIGS. 9 TO 12
The technique of combined open reduction and innominate osteotomy.



FIGS. 13 TO 16
The technique of combined open reduction and innominate osteotomy.

The femoral head is gently reduced under direct vision. Particular attention is paid to the degree of shortening of the iliopsoas muscle because a shortened iliopsoas not only renders reduction difficult but also limits abduction and medial rotation when the hip is reduced; under such circumstances the tendinous part of the iliopsoas should be divided. The stability of reduction is assessed at this time. The reduction is found to be stable with the hip in abduction, flexion and varying degrees of medial rotation; however, redislocation usually occurs laterally when the hip is adducted and anteriorly when the hip is either extended or laterally rotated. Under such circumstances innominate osteotomy is carried out.

Innominate osteotomy—The outer surface of the ilium having been previously exposed, attention is now directed to its inner surface. The cartilaginous iliac apophysis is displaced medially from the anterior half of the iliac crest with an elevator, and the periosteum of the inner surface of the ilium is stripped off in a continuous sheet to expose the sciatic notch (Fig. 7). Care is taken to remain in the subperiosteal plane throughout, but particularly behind the sciatic notch because of the proximity of the sciatic nerve and the superior gluteal artery. The tip of a curved forceps is passed subperiosteally behind the notch from the medial side in order to grasp one end of the Gigli saw (Fig. 9). The osteotomy extends in a straight line from the sciatic notch to the anterior inferior spine and is at right angles to the vertical axis of the ilium (Fig. 10). The soft tissues are retracted medially and laterally in order that the bone may be easily divided with the Gigli saw, which is considered to be a safer instrument than an osteotome for this purpose. A generous full thickness bone graft is then removed from the anterior part of the iliac crest with large bone cutting forceps (Fig. 10), and is trimmed to the shape of a wedge, the base of which should correspond approximately to the distance between the anterior superior and inferior spines (Fig. 11). Any temptation to reduce the base of this wedge should be resisted. One stout towel forceps is used to steady the proximal segment of the innominate bone, and a second is used to grasp the distal segment posterior to the anterior inferior spine. By means of a curved elevator in the sciatic notch and traction on the distal towel forceps the distal segment of the innominate bone containing the entire acetabulum is shifted forwards, downwards and outwards so that the osteotomy site is opened antero-laterally (Fig. 11). The best displacement of the distal segment is obtained by allowing the femoral head to remain in the dislocated position. It is most important to avoid any backward or inward displacement of the distal segment.

The wedge-shaped bone graft is then inserted on its edge into the osteotomy site; when traction is released the graft is found to be held firmly by the two segments of the innominate bone. Nevertheless, a stout Kirschner wire is inserted across the osteotomy site, through the graft and into the distal segment posterior to the acetabulum in order to prevent any subsequent shift of the graft or of the distal segment (Fig. 12). At this point the femoral head is reduced again and the stability of reduction is reassessed. If the displacement of the distal segment of the innominate bone has been correct it will be found that the reduction is now stable even with the hip in the functional position of walking. Throughout the remainder of the procedure an assistant holds the lower extremity with the hip in a position of slight abduction, slight flexion and slight medial rotation. The knee is kept flexed to overcome the relative shortening of the hamstring muscles.

The residual pocket of joint capsule, formerly occupied by the dislocated femoral head, is obliterated by appropriate excision of redundant capsule followed by careful suturing of the edges (Fig. 13). The two halves of the iliac apophysis are then sutured together over the iliac crest (Fig. 14). The Kirschner wire is cut so that its end lies in the subcutaneous fat (Fig. 15). The skin is closed with continuous intradermal stainless steel wire (Fig. 16). A unilateral hip spica is applied with the hip still in the same position of slight abduction, slight flexion and slight medial rotation. The knee is maintained in a flexed position to diminish the tension of the relatively short hamstring muscles and thereby prevent continuous compression of the articular cartilage of the hip joint during the period of immobilisation.

Throughout the operation bleeding is controlled by packing and coagulation. The amount of blood loss—measured by weighing sponges and recording suction volumes—varies from 100 to 200 millilitres and the time for the combined operation of open reduction and osteotomy is usually one hour.

Post-operative management—The hip spica is removed after six weeks and radiographs are taken. The Kirschner wire is removed under a general or local anaesthetic. Active movements are permitted, and as soon as muscle tone is satisfactory partial weight bearing with crutches is encouraged for a few weeks after which full weight bearing is allowed. In older children it is sometimes felt necessary to apply plaster boots with an abduction bar for a month before weight bearing is allowed.

INDICATIONS FOR INNOMINATE OSTEOTOMY

Although the main indication for innominate osteotomy is in the primary treatment of congenital dislocation of the hip in children aged eighteen months to six years, and of congenital subluxation up to early adult life, it is also indicated as a secondary treatment for residual or recurrent dislocation or subluxation after other methods of treatment.

Other conditions that can be treated by this method are paralytic dislocation or subluxation —whether from poliomyelitis, spina bifida or cerebral palsy; residual pathological dislocation or subluxation after septic arthritis; and subluxation of the hip secondary to a fixed pelvic obliquity such as occurs with an uncorrectable lumbar scoliosis.

CLINICAL MATERIAL

At the time of writing ninety-six innominate osteotomies have been done at the Hospital for Sick Children, Toronto, since November 1957. Of these, fifty-eight were done as the primary treatment in forty-one children. More than twice this number of children, mostly under the age of eighteen months, were treated conservatively during the same period.

The clinical material in this series consists of twenty-five congenitally abnormal hip joints in eighteen children aged eighteen months to six years at the time of initial treatment, the average being thirty-three months. They were all consecutive patients and the first innominate osteotomy was performed in November 1957. There were nineteen congenital dislocations and six congenital subluxations. The aforementioned regimen was the initial—and only—method of treatment used. The children were followed at regular intervals after operation; the follow-up period was taken from the time the child started to walk after the operation. The shortest follow-up was one year and the longest three years.

RESULTS

Clinical assessment of the early results of any method of treatment of congenital dislocation or subluxation of the hip in children tends to be misleading because the clinical result one or two years after treatment may be very satisfactory even in the presence of imperfect correction of the anatomical abnormality of the hip. It is well recognised, however, that unless the anatomical abnormality has been well corrected the clinical result gradually deteriorates.

Clinical assessment in the present group of patients included the range of hip movement, stability, the Trendelenburg test and gait. The results at the time of follow-up were excellent in twenty-four of the twenty-five hips.

Anatomical results—Radiographic assessment of the anatomical result is more significant than clinical assessment of joint function, particularly in respect of prognosis. Indeed, Putti (1933) said that " no complete or permanent restoration of function occurs without a perfect anatomical restoration."

The anatomical results have been assessed by the method of Severin (1941) using the CE (centre-edge) angle devised by Wiberg (1939).

FIG. 17

FIG. 18

Case 1—A two-year-old boy with previously untreated congenital dislocation of the right hip. Figure 17—Before operation. Figure 18—At the time of open reduction and innominate osteotomy of the right hip.

FIG. 19
Case 1—Two and three-quarter years after open reduction and innominate osteotomy.

Type I—The hip is perfect in all respects, with rounded head and normal neck and acetabulum: *a*) the CE angle is more than 19 degrees between the ages of six and thirteen; *b*) the CE angle is from 15 to 19 degrees between the ages of six and thirteen.
Type II—One or both of the head and neck of the femur reveal moderate deformity, the shape of the acetabulum is good and there is no subluxation: *a*) the CE angle is the same as in Type Ia; *b*) the CE angle is the same as in Type Ib.
Type III—There is dysplasia of the acetabulum but no subluxation of the joint. The CE angle is less than 15 degrees in ages from six to thirteen years.
Type IV—The femoral head is subluxated and articulates with a shallow acetabulum: *a*) positive CE angle, or equal to zero; *b*) the CE angle is negative because the subluxation is greater.
Type V—The femoral head articulates with a " secondary acetabulum " developed in the higher part or on the edge of the true acetabulum. In this type, as in Type IV, there is often considerable deformity of the head and neck of the femur.
Type VI—There is a complete dislocation.

This seems to be the most critical method of assessing both maintenance of complete reduction and osseous development of the acetabulum and femoral head.

The anatomical results are shown in Table I. It will be seen that all of the twenty-five hips may be considered excellent or good; there have been no poor results and no failures in this group of patients. The two Type III results were in the two hips of a girl aged five and a half at the time of treatment. Radiographs of six treated hips in four patients are shown in Figures 17 to 28 to demonstrate that the correction of the abnormal direction of the acetabulum has been maintained and there has been no evidence of growth disturbance of the pelvis. The donor site of the bone graft has filled in with new bone restoring the contour of the crest of the ilium.

Complications—There were no operative complications. One patient developed a superficial post-operative wound infection which subsided rapidly. Avascular necrosis of the femoral head occurred in one of the twenty-five hips. One child fell from a chair three months after operation and the hip redislocated; reduction was possible and the hip has remained stable since.

TABLE I

ANATOMICAL RESULTS IN TWENTY-FIVE HIPS TREATED BY INNOMINATE OSTEOTOMY ASSESSED BY THE METHOD OF SEVERIN (1941)

	Number of hips	Excellent		Good			Fair		Failures	
		Ia	Ib	IIa	IIb	III	IVa	IVb	V	VI
Dislocation	19	15	1	2	—	1	—	—	—	—
Subluxation	6	3	1	1	—	1	—	—	—	—
Total	25	18	2	3	—	2	—	—	—	—
Per cent of total		80		20			—		—	

DISCUSSION

Galen labelled the hip bone " os innominatum " (L., nameless bone) because its unique shape defied a concise descriptive term. Osteotomy through this bone involving a unique displacement presents a similar problem of etymology and therefore the author has designated the operation " innominate osteotomy."

Displacement of the osteotomy—Although innominate osteotomy is not a difficult procedure, the exact displacement of the distal segment as described above must be obtained with certainty in order that the underlying principle of the operation may be obeyed. The distal segment must not be allowed to displace posteriorly or medially because such displacement not only defeats the principle of the operation but also results in an undesirable decrease in the internal diameter of the pelvis.

The limbus—The role of the limbus in congenital dislocation of the hip is controversial and merits discussion (Somerville 1953, Platt 1956, Trevor 1957). The author believes that the limbus, or fibrocartilaginous labrum, is not actually turned in on itself, but rather that it has simply grown without restraint during the months or years that the femoral head has been dislocated; a similar phenomenon is seen in the overgrown fibro-fatty tissue, or pulvinar, in the base of the acetabulum. Wide exposure of the superior and anterior aspect of the hip joint permits reduction of the femoral head deep to the overgrown limbus, which then comes to lie external to the perimeter of the head, thereby adding both depth to the acetabulum and stability to the reduction. For these reasons the author believes that the fibrocartilaginous labrum, or limbus, should be preserved.

Valgus and anteversion of the femur—Both valgus and anteversion of the femur tend to militate against a stable reduction of the hip when the limb is in the functional position of walking. In the author's opinion both of these deformities are secondary to the dislocation or subluxation rather than primary, and usually correct spontaneously with subsequent use of the reduced hip provided the reduction remains stable. After innominate osteotomy the reduced hip is stable even in the presence of fairly marked valgus and anteversion, because the femoral head is better covered both laterally and anteriorly. Thus femoral osteotomy is obviated unless the femoral deformities are extreme. No femoral osteotomy was performed in the patients included in this report.

Secondary treatment—In many ways and for many reasons a congenitally dislocated hip that has been unsuccessfully treated presents a more difficult problem than one that has not

FIG. 20

FIG. 21

Case 2—A twenty-one-month-old girl with previously untreated congenital dislocation of the right hip. Figure 20—Before operation. Figure 21—Two and a half months after open reduction and innominate osteotomy.

FIG. 22

Case 2—Two and a half years later.

FIG. 23

Case 3—A five and a half-year-old girl with previously untreated congenital dislocation of the left hip and congenital subluxation of the right hip. Condition before operation.

FIG. 24

Case 3—Two and a half months after innominate osteotomy of right hip and two months after open reduction and innominate osteotomy of left hip.

FIG. 25

Case 3—Two years after innominate osteotomy of right hip, and open reduction and innominate osteotomy of left hip; the result in both was graded Type III.

been previously treated. It should be pointed out that, on the whole, the results of innominate osteotomy in the secondary management of an unsuccessfully treated hip cannot be expected to be as satisfactory as the results of innominate osteotomy in primary treatment.

Shape and capacity of the acetabulum—The various types of acetabuloplasty, including the effective operation of Pemberton (1958), are based on the principle of altering only the iliac component of the acetabulum and therefore must both alter its shape and decrease its capacity. The author believes that the principle of preserving the shape and capacity of the acetabulum is important to the future function of the joint; only a comparison of the long-term results of acetabuloplasty and innominate osteotomy will determine the importance of this principle.

ADVANTAGES OF INNOMINATE OSTEOTOMY

Correction of the abnormal direction in which the entire acetabulum faces provides immediate stability of reduction in the functional position of weight bearing without altering the congruity of the acetabulum or decreasing its capacity.

After innominate osteotomy the area of articular cartilage of the femoral head and acetabulum in contact in the functional position of weight bearing is considerably increased because the femoral head is better covered by the acetabulum. As a result, pressure of weight bearing is distributed over a larger area of articular cartilage; it is suggested that this may be an important factor in helping to prevent degenerative changes in the articular cartilage with subsequent function of the joint.

Both reduction and stability are provided by a single operative procedure; femoral osteotomy is obviated.

The stability of reduction permits early resumption of function of the hip, thereby avoiding the undesirable effects, as well as the hardships, of prolonged immobilisation.

FIG. 26

Case 4—A two and a quarter-year-old girl with previously untreated congenital dislocation of the right hip and congenital subluxation of the left hip. Condition before operation.

FIG. 27

Case 4—Two and a half months after open reduction and innominate osteotomy of the right hip and two months after innominate osteotomy of the left.

FIG. 28

Case 4—Two and three-quarters years after open reduction and innominate osteotomy of the right hip and innominate osteotomy of the left hip.

Early weight bearing on a completely reduced and completely stable hip seems likely to provide the best possible stimulus for subsequent normal development of both the femoral head and the acetabulum.

Many years must pass before the efficacy of innominate osteotomy can be assessed with any degree of certainty, but the early results are very encouraging. Early recognition is still, and will continue to be, the most important aspect of congenital dislocation and subluxation of the hip, and it is to be hoped that eventually all these children may be effectively treated by conservative means during the favourable first few months of life.

SUMMARY AND CONCLUSIONS

1. The problem of instability of reduction in congenital dislocation and congenital subluxation of the hip has been studied and it has been concluded that the basic cause of this instability is the abnormal direction in which the entire acetabulum faces.

2. An operation, innominate osteotomy, has been designed to correct the abnormal direction of the entire acetabulum in children over the age of eighteen months. The principle of innominate osteotomy is redirection of the acetabulum so that the reduced dislocation or subluxation, which previously was stable only in a position of abduction and flexion, is rendered stable in the functional position of weight bearing.

3. The operative technique, and the pre-operative and post-operative management are described.

4. The indications for innominate osteotomy are outlined and the advantages of the operation are enumerated.

5. The early results of innominate osteotomy are very encouraging.

The author wishes to express his gratitude to Miss Marguerite Drummond, medical artist, the Hospital for Sick Children, for the half-tone drawings of the operation, to her staff in the Department of Visual Education for the reproduction of radiographs, and to Dr O. R. McNeill for the photographs of the anatomical specimens.

REFERENCES

ALBEE, F. H. (1915): The Bone Graft Wedge. Its Use in the Treatment of Relapsing, Acquired, and Congenital Dislocation of the Hip. *New York Medical Journal*, **102,** 433.

BADGLEY, C. E. (1949): Etiology of Congenital Dislocation of the Hip. *Journal of Bone and Joint Surgery*, **31–A, 341.**

BOSWORTH, D. M., FIELDING, J. W., LIEBLER, W. A., ISHIZUKA, T., IKEUCHI, H., and COHEN, P. (1960): Hip Shelves in Children. *Journal of Bone and Joint Surgery*, **42–A,** 1,223.

CHIARI, K. (1955): Ergebnisse mit der Beckenosteotomie als Pfannendachplastik. (Results of pelvic osteotomy as of the shelf method of acetabular roof plastic.) *Zeitschrift für Orthopädie und ihre Grenzgebiete*, **87,** 14.

COLONNA, P. C. (1936): An Arthroplastic Operation for Congenital Dislocation of the Hip—a Two Stage Procedure. *Surgery, Gynecology and Obstetrics*, **63,** 777.

COLONNA, P. C. (1953): Capsular Arthroplasty for Congenital Dislocation of the Hip. *Journal of Bone and Joint Surgery*, **35–A,** 179.

COMPERE, E. L., and SCHNUTE, W. J. (1946): Treatment of Congenital Dislocation of the Hip. *Journal of Bone and Joint Surgery*, **28,** 555.

CREGO, C. H., Jun., and SCHWARTZMANN, J. R. (1948): Follow-up Study of the Early Treatment of Congenital Dislocation of the Hip. *Journal of Bone and Joint Surgery*, **30–A,** 428.

DICKSON, F. D. (1935): The Shelf Operation in the Treatment of Congenital Dislocation of the Hip. *Journal of Bone and Joint Surgery*, **17,** 43.

ESTEVE, R. (1960): Congenital Dislocation of the Hip. *Journal of Bone and Joint Surgery*, **42–B,** 253.

FARRELL, B. P., and HOWORTH, M. B. (1935): Open Reduction in Congenital Dislocation of the Hip. *Journal of Bone and Joint Surgery*, **17,** 35.

GALLOWAY, H. P. H. (1920): The Open Operation for Congenital Dislocation of the Hip. *Journal of Orthopaedic Surgery*, **2,** 390.

GILL, A. B. (1935): Plastic Construction of an Acetabulum in Congenital Dislocation of the Hip—The Shelf Operation. *Journal of Bone and Joint Surgery*, **17,** 48.

GILL, A. B. (1948): The End Results of Early Treatment of Congenital Dislocation of the Hip. *Journal of Bone and Joint Surgery*, **30–A,** 442.

GROVES, E. W. HEY (1928): The Treatment of Congenital Dislocation of the Hip-Joint with Special Reference to Open Operative Reduction. In *The Robert Jones Birthday Volume*, p. 73. London: Humphrey Milford Oxford University Press.

HASS, J. (1951): *Congenital Dislocation of the Hip.* Oxford: Blackwell Scientific Publications Ltd.

KAWAMURA, B. (1959): The Transverse Pelvic Osteotomy. *Journal of the Japanese Orthopaedic Society*, **32,** 65.

LANGENSKIÖLD, F. (1953): On the Transposition of the Ileopsoas-Muscle in Operative Reduction of Congenital Hip-Dislocation. *Acta Orthopaedica Scandinavica*, **22,** 295.

LAURENT, L. E. (1953): Congenital Dislocation of the Hip. *Acta Chirurgica Scandinavica*, Supplementum 179.

LEVEUF, J. (1948): Results of Open Reduction of " True " Congenital Luxation of the Hip. *Journal of Bone and Joint Surgery*, **30–A,** 875.

MCDONALD, J. L. (1934): *Personal Communication.*

MACKENZIE, I. G., SEDDON, H. J., and TREVOR, D. (1960): Congenital Dislocation of the Hip. *Journal of Bone and Joint Surgery*, **42–B,** 689.

MASSIE, W. K., and HOWORTH, M. B. (1951): Congenital Dislocation of the Hip. Part II. Results of Open Reduction as Seen in Early Adult Period. *Journal of Bone and Joint Surgery*, **33–A,** 171.

MULLER, G. M., and SEDDON, H. J. (1953): Late Results of Treatment of Congenital Dislocation of the Hip. *Journal of Bone and Joint Surgery*, **35–B,** 342.

PAUWELS, F. (1951): Des affections de la hanche d'origine mécanique et de leur traitement par l'ostéotomie d'adduction. *Revue de Chirurgie Orthopédique*, **37,** 22.

PEMBERTON, P. A. (1958): Osteotomy of the Ilium with Rotation of the Acetabular Roof for Congenital Dislocation of the Hip. Proceedings of the American Academy of Orthopaedic Surgeons. *Journal of Bone and Joint Surgery*, **40–A,** 724.

PEMBERTON, P. A. (1959): *Personal communication.*

PLATOU, E. (1953*a*): Rotation Osteotomy in the Treatment of Congenital Dislocation of the Hip. *Journal of Bone and Joint Surgery*, **35–A,** 48.

PLATOU, E. (1953*b*): Luxatio Coxae Congenita. A Follow-up Study of Four Hundred and Six Cases of Closed Reduction. *Journal of Bone and Joint Surgery*, **35–A,** 843.

PLATT, Sir H. (1956): Congenital Dislocation of the Hip: the Rôle of Open Reduction. In *Modern Trends in Orthopaedics*. Second series. Edited by Sir Harry Platt. London: Butterworth & Co. (Publishers) Ltd.

PONSETI, I. (1944): Causes of Failure in the Treatment of Congenital Dislocation of the Hip. *Journal of Bone and Joint Surgery*, **26,** 775.

PONSETI, I. (1946): Pathomechanics of the Hip After the Shelf Operation. *Journal of Bone and Joint Surgery*, **28,** 229.

PONSETI, I. V., and FRIGERIO, E. R. (1959): Results of Treatment of Congenital Dislocation of the Hip. *Journal of Bone and Joint Surgery*, **41–A,** 823.

PUTTI, V. (1933): Early Treatment of Congenital Dislocation of the Hip. *Journal of Bone and Joint Surgery*, **15,** 16.

SALTER, R. B., and FIELD, P. (1960): The Effects of Continuous Compression on Living Articular Cartilage. An Experimental Investigation. *Journal of Bone and Joint Surgery*, **42–A,** 31.

SCHWARTZ, R. P. (1945): V Plaster Splint for Maintaining Reduction of Congenital Dislocation of the Hip. *Journal of Bone and Joint Surgery*, **27,** 166.

SEVERIN, E. (1941): Contribution to the Knowledge of Congenital Dislocation of the Hip Joint. *Acta Chirurgica Scandinavica*, **84,** Supplementum 63.

SHANDS, A. R., Jun., and STEELE, M. K. (1958): Torsion of the Femur. *Journal of Bone and Joint Surgery*, **40–A,** 803.

SMITH-PETERSEN, M. N. (1917): A new supra-articular subperiosteal approach to the hip joint. *American Journal of Orthopedic Surgery*, **15,** 592.

SOMERVILLE, E. W. (1953): Open Reduction in Congenital Dislocation of the Hip. *Journal of Bone and Joint Surgery*, **35–B,** 363.

SOMERVILLE, E. W., and SCOTT, J. C. (1957): The Direct Approach to Congenital Dislocation of the Hip. *Journal of Bone and Joint Surgery*, **39–B,** 623.

TREVOR, D. (1957): Treatment of Congenital Dislocation of the Hip. *Journal of Bone and Joint Surgery*, **39–B,** 611.

TREVOR, D. (1958): Osteotomy in the Treatment of Congenital Dislocation of the Hip. *Proceedings of the Royal Society of Medicine* (Section of Orthopaedics), **51,** 1,045.

WIBERG, G. (1939): Studies on Dysplastic Acetabular and Congenital Subluxation of the Hip Joint, with Special Reference to the Complication of Osteo-arthritis. *Acta Chirurgica Scandinavica*, **83,** Supplementum 58.

WIBERG, G. (1953): Shelf Operation in Congenital Dysplasia of the Acetabulum and in Subluxation and Dislocation of the Hip. *Journal of Bone and Joint Surgery*, **35–A,** 65.

WILKINSON, J., and CARTER, C. (1960): Congenital Dislocation of the Hip. *Journal of Bone and Joint Surgery*, **42–B,** 669.

COMPRESSION STRESS FRACTURES IN MAN AND THE GREYHOUND

M. B. DEVAS, HASTINGS, ENGLAND

From the Stress Fracture Bureau, the Middlesex Hospital, London

Compression stress fractures are not to be newly described in this paper; rather they are to be considered as an entity in themselves to allow the recognition of another variety of stress fractures in clinical practice. Nomenclature has tended to be descriptive of the occasion on, or activity in which the stress fracture occurred, and this has masked the fact that many stress fractures have a common pattern, despite the difference of age, occupation or sex of the patient. Thus the runner's fracture (Devas and Sweetnam 1956) and that of middle-aged

FIG. 1

FIG. 2

Case 1—This girl, aged nine, developed pain in the upper left shin. After ten days a radiograph showed a slight haze of internal callus at the junction of the middle and uppermost thirds of the tibia (Fig. 1) which, after a further two weeks, had increased considerably. This is typical of a compression stress fracture (Fig. 2). There is little external callus in comparison with the amount of internal callus, and no fracture line can be seen in the cortices.

women (Burrows 1940) are one and the same; the " shin soreness " stress fracture of the tibia (Devas 1958) also resembles the latter, but, because of the different structure of the bone in which it occurs, it is rarely complete; the " recruit's fracture " of the upper tibia may also belong to this category. However, the transverse fracture of the same bone, described in

ballet dancers by Burrows (1956), is quite different, as is the longitudinal stress fracture (Devas 1960), both having different radiological patterns and doubtless a different causative mechanism.

Fractures arising from injury fall into many categories, one of which is compression, and the same is true of stress fractures. That the greyhound should also suffer from this variety—amongst others—is of particular interest, as will be shown below.

The bones most frequently affected by compression stress fractures are the tibia in its uppermost part in children and its lowermost part in the older person, and the calcaneum. The neck of the femur and the pelvis also suffer compression stress fractures, as well as other

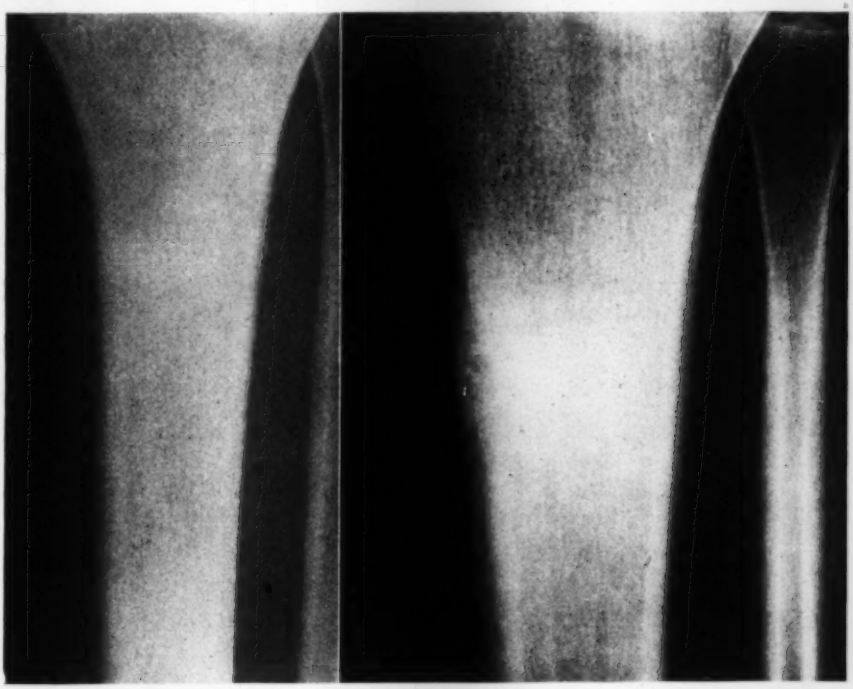


FIG. 3 FIG. 4

Case 2—A boy aged twelve complained of pain in the upper part of his left tibia, which was slightly swollen and tender. A radiograph a week after the onset of symptoms showed a thin haze of periosteal new bone (Fig. 3). Two weeks later the fracture was obvious in the radiographs but the internal callus has been screened by the external so that it does not show very clearly. One cortex can be seen to have fractured (Fig. 4). Two months after first being seen the child was free of symptoms, having had no treatment other than caution in the use of the limb. This fracture is not uncommon in children and is typical in its behaviour.

bones, but there is insufficient material as yet either in the literature or in the stress fracture bureau to allow these to be considered in detail.

A compression stress fracture can occur without apparent solution of continuity, and its presence may be confirmed only by the development and recession of internal callus; there may be no external callus whatsoever—particularly in the calcaneum. This, of course, is by no means always the case; indeed, gross deformity can occur, particularly in the elderly. In general the symptoms and signs are similar to those of other varieties of stress fracture. Here, however, it is again of value to emphasise that radiological confirmation can be delayed for several months, to an even greater extent than in other types of this fracture.

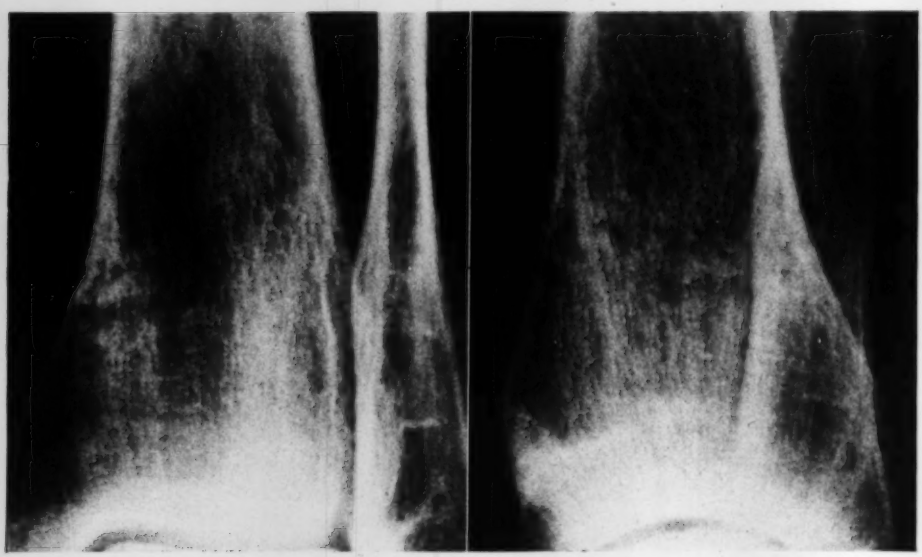


FIG. 5

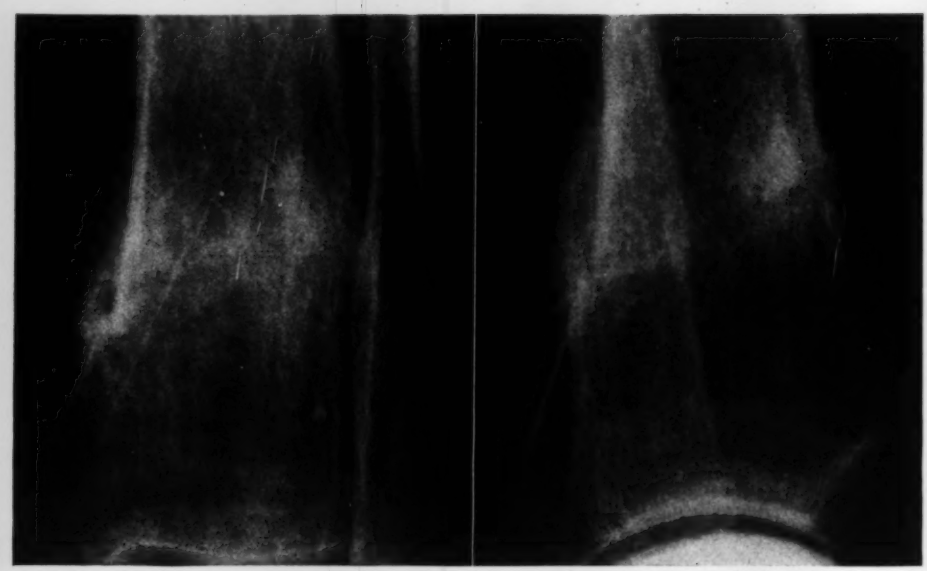


FIG. 6

Case 3—A woman believed she was a stork and stood on one leg for long periods in a lunatic asylum. One day she was found to be unable to walk and the radiograph showed a typical compression stress fracture of the lowest third of the tibia on which she was wont to stand (Fig. 5). There was little displacement, but there was a haze of internal callus across the tibia at the level of the fracture. Later considerable callus developed outside the cortex (Fig. 6). This is a favourite site for stress fractures in elderly patients with slight osteoporosis. Sometimes there may be considerable displacement.

FIG. 7

FIG. 8

Case 4—This woman of sixty-nine fell and broke her hip, necessitating Smith-Petersen pin fixation. Three months after returning to full weight bearing, and four months after the fracture, she developed pain above the left ankle, which the author confidently diagnosed as a stress fracture of the fibula. However, radiographs remained normal for four months, when a compression stress fracture began to show in the tibia (Fig. 7). Her symptoms continued, and after a further month the fracture was typical of the compression variety (Fig. 8). Symptoms finally settled at the end of seven months. This patient showed only a little external callus postero-medially.

RADIOLOGY

The compression stress fracture that occurs in the normal healthy living bone of an adult does not always show a fracture line in radiographs, although there must be some solution of continuity if external callus is formed. All that is seen initially is a hazy cloud of increased bone density at the site of the fracture (Figs. 1 and 2). The shadow does not represent bone compressed into itself because it can occur without any deformity; it represents internal callus being laid down within the cancellous bone and is not due to callus outside the cortex. External callus forms in many compression fractures but does not, except in children (Figs. 3 and 4), appear so quickly that the original internal callus cannot be seen. If the compression stress continues, the bone may concertina on itself and show not only a fracture of the cortex (Fig. 5) but slight deformity (Fig. 15).

FIG. 9

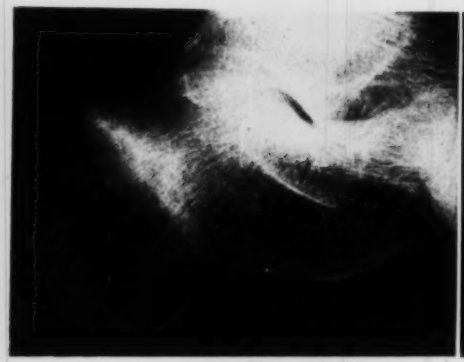


FIG. 10

FIG. 11

Case 5—A woman of sixty-seven, with mild diabetes, but otherwise well, developed pain in the right heel on walking. Two weeks later a more severe pain developed in the left heel, but the symptoms improved on the right (probably due to limitation of activity because of the pain on the left side). After a further three weeks she attended for treatment, and the radiographs (Figs. 9 and 10) showed bilateral compression stress fractures of the calcanea. Clinically she was tender all round both the affected bones, with pain in each on forced plantar flexion against resistance as when standing on tiptoe. A few weeks later a radiograph showed a second line of internal callus—that is, a second stress fracture—on the left (Fig. 11). This appearance is not uncommon, and both fractures developed at the same time. She continued to have symptoms for several months but was able to get about her daily duties with simple measures, such as firm binding of the feet and calves and sponge rubber heel pads.

CLINICAL VARIETIES

The tibia in children—The child with a stress fracture of the tibia develops pain and a limp; swelling may or may not be obvious. Tenderness varies both in degree and in the length of the shaft affected.

The earliest radiological sign may be either a haze of increased density across the upper part of the tibial shaft (Figs. 1 and 2) or a thin line of callus which delineates the haematoma around the fracture (Fig. 3), or both. The appearance is often suggestive of a neoplasm. However, in this particular stress fracture the radiological change occurs rapidly, and in a few days further calcification within the haematoma, which remains the same size—provided the limb is at rest—confirms the diagnosis (Fig. 4). Nevertheless, if there is doubt a biopsy must be done.

The tibia in the older person—Middle-aged and old people frequently develop stress fractures of the lowest third of the tibia, but, unlike those in young adults, the fracture is transverse (Figs. 5 to 8). Sometimes the onset of pain is sudden and the patient falls to the ground and is thus thought to have caused the fracture by falling. In others it is more gradual. The fracture at this site is not always obvious if the initial haze of bone is not recognised for what it is (Figs. 7 and 8).

FIG. 12

Case 6—A man aged forty-nine was kick-starting a motor mower when it backfired. The pedal under the ball of his foot forced the ankle into dorsiflexion against the resistance of his calf muscles. A fracture, with some displacement, but following the line of a compression stress fracture, was caused by this violence transmitted through the long plantar ligament in one direction and resisted by the calcaneal tendon and its muscles in the other. This caused compression of the tuberosity of the calcaneum. It is probable that it is this mechanism that causes the compression stress fractures in this bone that occur in marching or walking.

The calcaneum—This fracture has been well documented in young adults (Hullinger 1944, Leabhart 1959, Winfield and Dennis 1959) but it also occurs in the older person. It is perhaps the best example of simple compression. Pain in the heel, with or without radiological evidence of a calcaneal spur, may be caused by a stress fracture. Some of the painful heels that are seen so commonly in clinical practice and eventually clear up without a satisfactory diagnosis are no doubt due to this condition. Clinical examination will reveal considerable tenderness on both sides of the calcaneum, as well as below on the ball of the heel, and up the calcaneal tendon, and sometimes there is swelling posteriorly in this region. Standing on tiptoe may cause the pain, as does walking or other similar activities. This fracture may take a long

FIG. 13

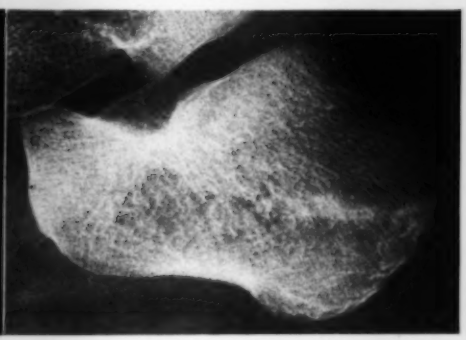


FIG. 14

Case 7—This boy fell from the roof of a shed and landed on his heels. The symptoms suggested a fracture of the calcaneum, but the first radiograph was normal (Fig. 13). Three weeks later a traumatic compression fracture can be seen quite clearly (Fig. 14), but the direction of the internal callus is quite different from that in a compression stress fracture, for here it runs horizontally and at right angles to the line of force that caused the fracture.

time to show radiologically and the changes may be very slight, especially if treatment is given promptly by reduction of activity and provision of a sponge heel pad. Figures 9 to 11 illustrate this; they show the thin haze of bone, roughly parallel to the line of the cortex of the tuberosity, but with no break in the cortex (Hullinger 1944)—although this has been seen occasionally. It is also important to realise that the fracture " haze " may on occasion be double, as in the left heel of Case 5 (Fig. 11).

The mechanism of this type of stress fracture is interesting. It is not caused by the heel thumping down on the ground when walking, but by compression across the neck of the calcaneum from the calcaneal tendon pulling hard on the upper part of the tuberosity, the pull being resisted by the long plantar ligament attached to the lower part. Figure 12 illustrates this. It is the radiograph of a man who, when pressing the kick starter of a motor mower with his forefoot, had his ankle suddenly dorsiflexed by the motor back-firing. There was no direct violence to the heel, yet he sustained a fracture at the same site as a stress fracture and one with a similar shape and direction, but with slight deformity. When a fracture of the calcaneum occurs from landing heavily on the heels in a fall from a height the direction of the fracture line is different. This is shown in Figures 13 and 14. This boy fell on to his heels from a shed; the clinical diagnosis was beyond doubt, yet there was initially no radiological confirmation. Three weeks later the fracture could be seen, with no deformity but with internal callus developing. Although this has the same hazy outline as that of a stress fracture, the site and direction are quite different.

FIG. 15

Case 8—A compression stress fracture of the neck of the femur in which there has been slight displacement, and with internal callus to be seen right across the base of the neck. This occurred in a middle-aged lady who had previously had a stress fracture of the fibula.

Other bones. *The femur*—The femoral neck can sustain stress fractures. Some of these have little or no displacement, and are compression stress fractures; they show first on the under part of the neck with the usual internal callus (Figs. 15 to 19). Even if the patient continues to bear weight the fracture may not disrupt, but it is wise to use internal fixation not only for safety but also to avoid the lengthy disability that occurs with conservative treatment.

The pelvis—The stress fractures that occur in the inferior pubic and ischial rami seem to follow the pattern of compression, but here, with a different bone structure, the internal callus is not seen so clearly (Figs. 20 and 21).

The first metatarsal bone—Only one example has been seen, but the appearance was so typical of a compression fracture that there can be no doubt about the diagnosis (Figs. 22 and 23).

COMPRESSION STRESS FRACTURES IN THE GREYHOUND

The calcaneum and navicular bone frequently sustain stress fractures in the greyhound. This interesting condition has been observed for many years, and Mr J. K. Bateman, to whom I am indebted not only for my knowledge of this condition but also for the illustrations,

FIG. 16

FIG. 17

FIG. 18

FIG. 19

FIGS. 16 TO 19

Case 9—A very obese girl of twenty-four complained of pain in the left hip and thigh, with no history of injury, and worse towards the end of the day. After one month she was radiographed at the request of her own doctor, and this was thought to be normal, but on close inspection and in the light of later knowledge, a small hazy line can be seen in the bone of the left femoral neck (Fig. 16). Two months later the pain was still continuing and a further radiograph (Fig. 17) confirmed the site of the lesion and showed new bone formation on the under part of the neck of the femur. Meanwhile, blood investigations had been of no help, as everything was normal. After a further two months the stress fracture was consolidating (Fig. 18); the patient had remained all the while up and about. A tomograph after a further two months, that is, six months after the onset of symptoms (Fig. 19), showed the fracture line clearly. Eight months later she was discharged free of symptoms.

FIG. 20

FIG. 21

Case 10—An elderly lady, who had noticed a little pain in the region of the left hip, spent three hours at a church service after which the pain became severe. Thereafter all movements of the leg or pelvis were painful. A radiograph taken a few days later showed a stress fracture of the inferior pubic ramus (Fig. 20) and one month later the fracture was consolidating (Fig. 21). The appearances in the radiograph suggest a compression stress fracture.

FIG. 22

FIG. 23

Case 11—A girl aged twenty pushed a delivery cart on a milk round for one month and then developed pain on the inner side of the right foot. This was worse with exercise and better with rest. Clinically there was tenderness at the base of the first metatarsal, and a radiograph confirmed the presence of a compression stress fracture (Fig. 22). Three months later the fracture was disappearing (Fig. 23). The characteristic haze of new bone produced by internal callus allowed the diagnosis to be made with certainty from the radiographs.

has operated on both these fractures successfully, so that the greyhounds not only return to racing but also win.

The interest in the navicular fracture in the greyhound lies in the fact that it always occurs on the right side. The dogs always race anti-clockwise round the track, so that the

FIG. 24

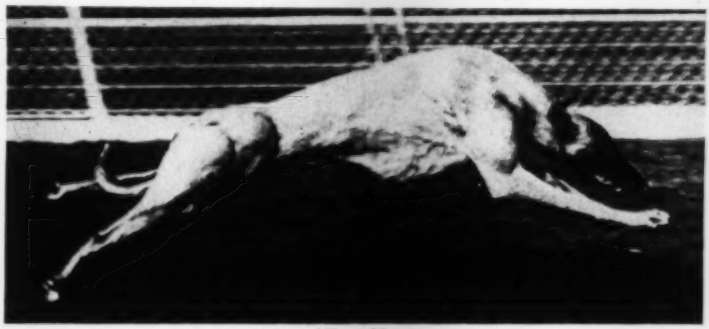


FIG. 25

FIG. 26

Greyhounds racing at speeds of about thirty miles an hour give a terrific thrust off the hind feet. Notice in Figures 24 and 25 that the hind foot itself does not move; but the ankle and forefoot have a wide range of movement. Figure 26 shows greyhounds cornering to the left at speed. If not in the correct step, the right hind leg requires a considerable additional thrust to push the dog to the left.

right hind leg has additional work, and therefore increased stress, in pushing the dog round the corner to the left. When it is realised that the greyhound races at speeds up to or over thirty miles an hour, the extra force required to change direction sharply is considerable

(Figs. 24 to 26). Normally the dog, turning left, leans over to the left with the left hind leg well underneath; but if " out of step " at the crucial moment, the right hind leg takes the cornering strain. According to Bateman (1958, 1960) it is this type of incident that causes the stress fracture of either the navicular bone or calcaneum (Figs. 27 and 28). No trauma is involved.

For practical purposes the midtarsal joints of the hind foot of the greyhound are devoid of movement; they transmit the tremendous thrust from the hind leg to the forefoot in the

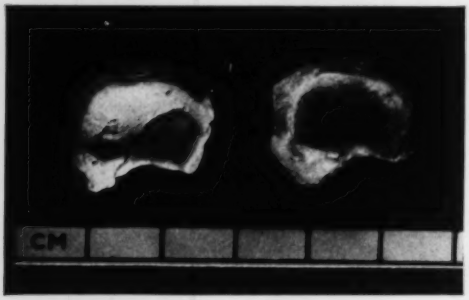


FIG. 27

On the left is a dried specimen of a navicular bone from a greyhound showing a stress fracture. On the right is a right navicular bone from a greyhound. The lateral half is heavily " bruised." This discoloration occurs right through the bone.

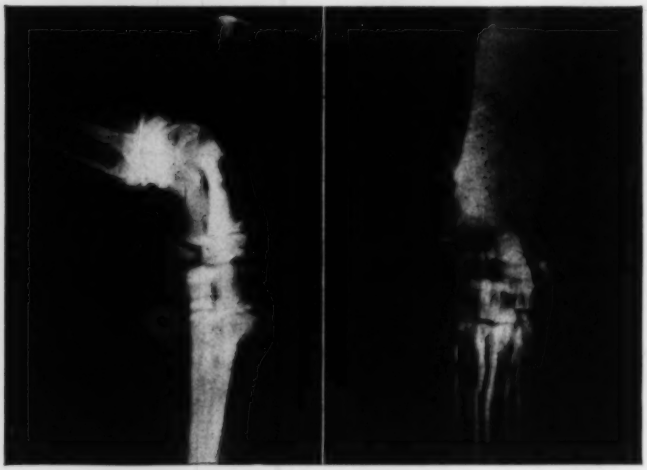


FIG. 28

Lateral and antero-posterior views of the right hind foot of a greyhound with a stress fracture of the navicular bone, part of which has been extruded.

manner of a lever. There is, therefore, a compression thrust from the talus through the navicular bone, which, when it breaks, tends to have the fragments extruded (Figs. 27 and 28). It is of interest that the lack of midtarsal movement allows the navicular bone either to be held in place by a metal plate screwed to the talus above and the cuneiform bones below, or to be equally successfully replaced by a Perspex prosthesis.

The calcaneum is broken by the pull of the calcaneal tendon; in the greyhound this is not a compression fracture because the length and angle of the posterior part of the calcaneum

are longer and straighter than in man (Fig. 28). Often both the navicular bone and the calcaneum are broken, because it is probable that the greyhound will continue to run with a fractured navicular bone, only to fracture the calcaneum a few moments later. It is presumed that the loss of length of the foot from the compression fracture of the navicular bone relaxes the long plantar ligaments, thereby allowing a greater strain on the neck of the calcaneum.

DISCUSSION

One interesting feature of the navicular bone of the greyhound is that, when taken from a normal animal, it frequently shows bruising, almost invariably worse on the right, though it can be quite marked on the left (Fig. 27). This indicates that there has been soft-tissue damage within the bone, though the bone itself has not broken. In navicular bones that have been examined after fracture this " bruising " is usually present (Bateman 1960). Although many theories on the fatigue of bone have been advanced, it must also be considered that a stress fracture may, in fact, be a pathological fracture occurring in bone in which the soft-tissue elements, either within the bone or on its surface, have been damaged, with impairment of the blood supply to a certain part of the bone. Thus, in that part, the bone is deprived of its ability to undergo continuous reconstitution and it remains no longer healthy, and perhaps, in fact, no longer living. Under these circumstances fatigue, in the metallurgical sense, would set in, a small break would appear, and this would cause further pathological changes with further oedema of the soft tissues to compress the blood supply and a vicious circle would soon be in operation. It must, however, be emphasised that it is extremely unlikely that there should be but one cause for all forms of stress fractures.

SUMMARY

1. Compression stress fractures are described.
2. These fractures have all been previously described in various bones but have not been associated as a clinical or radiological entity.
3. The greyhound suffers a compression stress fracture of the navicular bone. This is described with certain deductions therefrom.

It would be invidious to single out those of my colleagues at home or abroad whose patients are described here; so I can only record my great gratitude to all who have sent, and still are sending, stress fractures to me. I do owe, however, a very special debt to Mr J. K. Bateman for his help and instruction, as well as for the photographs and radiographs of the greyhounds. I would also like to thank Mr P. H. Newman for his continued support, and Mr M. Turney of the Photographic Department, Middlesex Hospital, for his invaluable assistance.

REFERENCES

BATEMAN, J. K. (1958): Broken Hock in the Greyhound: Repair Methods and the Plastic Scaphoid. *Veterinary Record*, **70**, 621.

BATEMAN, J. K. (1960): *Personal Communication.*

BURROWS, H. J. (1940): Spontaneous Fracture of the Apparently Normal Fibula in its Lowest Third. *British Journal of Surgery*, **28**, 82.

BURROWS, H. J. (1956): Fatigue Infraction of the Middle of the Tibia in Ballet Dancers. *Journal of Bone and Joint Surgery*, **38–B**, 83.

DEVAS, M. B. (1958): Stress Fractures of the Tibia in Athletes, or " Shin Soreness." *Journal of Bone and Joint Surgery*, **40–B**, 227.

DEVAS, M. B. (1960): Longitudinal Stress Fractures. *Journal of Bone and Joint Surgery*, **42–B**, 508.

DEVAS, M. B., and SWEETNAM, R. (1956): Stress Fracture of the Fibula. *Journal of Bone and Joint Surgery*, **38–B**, 818.

HULLINGER, C. W. (1944): Insufficiency Fracture of the Calcaneus, Similar to March Fracture of the Metatarsal. *Journal of Bone and Joint Surgery*, **26**, 751.

LEABHART, J. W. (1959): Stress Fractures of the Calcaneus. *Journal of Bone and Joint Surgery*, **41–A**, 1,285.

WINFIELD, A. C., and DENNIS, J. M. (1959): Stress Fractures of the Calcaneus. *Radiology*, **72**, 415.

REDUCTION OF CERVICAL DISLOCATIONS

DAVID K. EVANS, SHEFFIELD, ENGLAND

From the Royal Infirmary, Sheffield

It is generally agreed that when pressure on the spinal cord or nerve roots occurs as a result of cervical dislocation it is desirable to relieve it as soon as possible. Ellis (1946) noted that rapid recovery of paraplegia might occur if any pressure on the cord could be relieved in a few hours. He stressed that "it is essential that these injuries be treated as extreme emergencies." Similarly, root damage may be lessened if reduction is effected promptly.

MANUAL MANIPULATION

The quickest method of reducing cervical dislocations is by manual manipulation, and Walton in 1893 was the first to describe a logical procedure. His manoeuvre consisted in full rotation to disengage the facets, followed by full lateral flexion to lift the forward facet above the posterior; then rotation in the opposite direction to replace the facets in their

FIG. 1 FIG. 2

Case 9. Figure 1—Before reduction. Figure 2—Reduction after passage of endotracheal tube. No manipulation.

normal relationship, the manipulation being completed by hyperextending the neck. Taylor (1924) advocated a less violent method which remains the basis for present practice. He pulled out the locked processes, using traction through a head sling. These manipulations were performed under general anaesthesia, and they gained many supporters. Roberts (1937) stated that "when the dislocation is complete, reduction must be attempted only under anaesthesia . . . the administration of an anaesthetic is not a dangerous procedure." Crooks and Birkett (1944) thought that the simplest and safest way to obtain reduction was by traction of the neck by halter and counter-traction on the legs by assistants, while Pentothal was given intravenously. "The surgeon holds the head in his hands and eases the reduction by gentle manipulation." Brookes (1933) reported thirty-six successful manipulations without a death.

In spite of these views, and probably in consequence of violent manipulations under indifferent anaesthesia, there developed a growing opinion that manipulation under anaesthesia was dangerous. For example, Rogers (1942) stated: "closed manipulation has led to cord

injury and death." Ellis (1946) thought it to be " moderately dangerous." (Nevertheless, he employed it when traction failed, and with success in three of his twenty cases.) Durbin (1957) thought that manipulation under anaesthesia might increase the degree of paralysis.

FIG. 3

FIG. 4

Case 7. Figure 3—Before reduction. Figure 4—After reduction by traction with slight rotation.

FIG. 5

FIG. 6

Case 17. Figure 5—Before reduction. Note that this is a hyperextension fracture-dislocation, the fracture taking place through the pedicles. Figure 6—Simple traction effected reduction, which was maintained by immobilisation in slight flexion.

Since upward " coning " of haemorrhage and oedema in the cord, leading to increase in paralysis and often to death, is common in these dislocations, it is possible that this unavoidable sequel may hitherto have been wrongly attributed to the manipulation.

TABLE I

CLINICAL DETAILS IN SEVENTEEN CASES OF CERVICAL DISLOCATION REDUCED MANUALLY UNDER ANAESTHESIA

Case number	Age (*years*)	Vertebral level	Extent of root or cord damage	Outcome
1	57	3 on 4	No damage to roots or cord	Full recovery
2	44	5 on 6	No damage to roots or cord	Full recovery
3	3	3 on 4	No damage to roots or cord	Full recovery
4	49	5 on 6	No damage to roots or cord	Full recovery
5	58	4 on 5	Weakness of finger flexors	Full recovery
6	36	4 on 5	Weakness of right deltoid only	Full recovery
7	42	4 on 5	Weakness of forearm muscles (right and left)	Full recovery
8	50	5 on 6	Weak triceps and all forearm muscles (right and left). Sensory blunting C.6 on left	Full motor recovery. Sensory blunting left thumb
9	37	6 on 7	Weak triceps, forearm muscles and intrinsics of hand. Sensory blunting C.6, 7 and 8 on right	Full motor recovery. Residual sensory blunting finger-tips on right
10	53	6 on 7	Weak triceps and forearm muscles	Residual weakness triceps and wrist extensors less than originally
11	60	4 on 5	Weak forearm muscles and intrinsics of hand	Weakness of hand and forearm unchanged
12	47	4 on 5	Complete paralysis arms and legs below lesion	Death twenty-four hours
13	51	5 on 6	Complete paralysis arms and legs below lesion	Death fourteenth day
14	14	3 on 4	Complete paralysis arms and legs below lesion	Residual spastic paresis left arm and leg. Attends ordinary school
15	25	5 on 6	Complete paralysis arms and legs below lesion	Residual spastic paresis. Walks easily with one stick
16	42	6 on 7	Complete paralysis arms and legs below lesion	Still alive. Paralysis unchanged
17	55	6 on 7	Complete paralysis arms and legs below lesion	Return of power in legs and arms. Still improving

SLOW REDUCTION BY TRACTION

These critical opinions, together with the introduction of skull calipers (Crutchfield 1933), brought about the gradual abandonment of manipulations with anaesthesia. The practice of slow reduction of the dislocation by increasing traction on the skull calipers, which had been inserted under local anaesthesia, became general. Barnes (1948) stated: " skeletal traction by means of skull calipers is the treatment of choice."

Nevertheless there are certain disadvantages of the method. It often fails. Four per cent of Durbin's series of fifty-three dislocations and fracture-dislocations required open reduction. The application of skull calipers under local anaesthesia is unpleasant for the patient. Repeated radiography requiring traction on the arms to show the lower cervical vertebrae is very painful. Moreover, until reduction is achieved routine two-hourly turning of the paraplegic patient is impossible and the risk of pressure ulceration is increased.

REDUCTION UNDER GENERAL ANAESTHESIA WITH A RELAXANT

In 1947 a patient with a traumatic dislocation of the fourth on the fifth cervical vertebra was admitted to the Sheffield Royal Infirmary under the care of Mr F. W. Holdsworth. Skull calipers were inserted under local anaesthesia and increasing traction was applied. The dislocation failed to reduce, and a general anaesthetic was given for open reduction. As the endotracheal tube was passed a slight click was heard, and when the cervical spine was exposed the dislocation was found reduced.

Since that time cervical dislocations have been reduced under general anaesthesia in this Unit. Induction is by intravenous Pentothal followed by Scoline. The anaesthetist then carefully passes an endotracheal tube. Radiographs taken at this stage often show the dislocation to be reduced (Figs. 1 and 2). If it is not, traction on the head with slight rotation effects reduction (Figs. 3 to 6). It is our impression that the relaxant plays a considerable part in the ease of reduction. Skull calipers are then inserted and the reduction maintained with seven to ten pounds' traction. The width of the Blackburn apparatus is an obstacle to easy nursing if two-hourly turning of the tetraplegic patient is necessary, and the Vinke or Crutchfield tongs are now preferred.

Two to three weeks after reduction, wiring and grafting of the affected vertebrae are performed using iliac bone (Gallie 1939). When the wound has healed, a polythene collar is fitted and the skeletal traction discarded. The patient is then allowed up and the collar is worn until fusion is sound.

RESULTS

This method of reduction has been found to be easy, quick, more pleasant for the patient, and, above all, safe. Seventeen patients have been treated in this way. Details are shown in Table I.

No patient with an incomplete paralysis was made worse, and no patient devoid of neurological damage sustained any during treatment. Of the patients seen originally with clinically complete lesions, two made excellent recoveries and one is unchanged a year after the injury. The patient in the most recent case is gaining power rapidly in both legs. The mortality in this group compares favourably with that of other series. There was no failure of reduction.

SUMMARY

1. The trends in treatment of cervical dislocation are reviewed.
2. Seventeen patients treated by manual reduction under general anaesthesia are reported.
3. The evidence is that reduction in this way is not dangerous and has advantages over other methods.

It is a pleasure to thank Mr F. W. Holdsworth and Mr W. J. W. Sharrard for their help and encouragement in the preparation of this paper, and for permission to report their cases.

REFERENCES

BARNES, R. (1948): Paraplegia in Cervical Spine Injuries. *Journal of Bone and Joint Surgery*, **30–B,** 234.

BROOKES, T. P. (1933): Dislocations of the Cervical Spine. Their Complications and Treatment. *Surgery, Gynecology and Obstetrics*, **57,** 772.

CROOKS, F., and BIRKETT, A. N. (1944): Fractures and Dislocations of the Cervical Spine. *British Journal of Surgery*, **31,** 252.

CRUTCHFIELD, W. G. (1933): Skeletal Traction for Dislocation of the Cervical Spine. Report of a Case. *Southern Surgeon*, **2,** 156.

DURBIN, F. C. (1957): Fracture-Dislocations of the Cervical Spine. *Journal of Bone and Joint Surgery*, **39–B,** 23.

ELLIS, V. H. (1946): Injuries of the Cervical Vertebrae. *Proceedings of the Royal Society of Medicine* (Section of Orthopaedics), **40,** 19.

GALLIE, W. E. (1939): Fractures and Dislocations of the Cervical Spine. *American Journal of Surgery*, **N.S. 46,** 495.

ROBERTS, S. M. (1937): Fractures and Dislocations of the Cervical Spine. Part II. *Journal of Bone and Joint Surgery*, **19,** 477.

ROGERS, W. A. (1942): Treatment of Fracture-Dislocation of the Cervical Spine. *Journal of Bone and Joint Surgery*, **24,** 245.

TAYLOR, A. S. (1924): Fracture-Dislocation of the Neck. A Method of Treatment. *Archives of Neurology and Psychiatry*, **12,** 625.

WALTON, G. L. (1893): A New Method of Reducing Dislocation of Cervical Vertebrae. *Journal of Nervous and Mental Disease*, **20,** 609.

INTRASPINAL EPIDERMOID TUMOURS IN THE LUMBAR REGION OF CHILDREN

N. J. BLOCKEY and J. SCHORSTEIN, GLASGOW, SCOTLAND

From the Orthopaedic Department, Royal Hospital for Sick Children, and the Neurosurgical Unit, Killearn Hospital, near Glasgow

This report concerns six children who for some months had complained of stiffness and pain in the low back and who turned out to have one or more intradural epidermoid tumours in the lumbar region of the spinal canal. Our patients were entirely similar to the six reported in 1956 by Choremis, Øeconomos, Papadatos and Gargoulas and to the four added in 1957 by Øeconomos and Caracalos. These ten had had tuberculous meningitis some years previously and had been treated by intrathecal injections of streptomycin. The authors suggested that the tumours owed their origin to epithelial cells implanted during lumbar puncture. Our six patients had also had lumbar punctures six to ten years previously; four had suffered from tuberculous meningitis, one from pyogenic meningitis and another from an obscure feverish illness with signs of meningeal irritation. The two who did not suffer from tuberculous meningitis had only five and two lumbar punctures respectively (Table I).

TABLE I

CLINICAL FEATURES IN THE SIX CHILDREN

Case number	Age in years at onset of present symptoms	Interval in years between onset and previous lumbar punctures	Number of lumbar punctures performed	Type of meningitis treated	Number and site of epidermoids
1	8	6	2	Pyogenic	1 Lumbar 2–4
2	12	9	60	Tuberculous	1 Lumbar 2–4
3	9	6	62	Tuberculous	1 Lumbar 2–4
4	9	7	Many	Tuberculous	3 Lumbar 2–5
5	9	8	5	Pyogenic	1 Lumbar 2–3
6	12	10	Many	Tuberculous	2 Lumbar 2–4

CLINICAL FEATURES

The history, symptoms and signs were so similar as to make separate detailed descriptions unnecessary. The outstanding features were rigidity of the lumbar spine in an otherwise healthy child who some years previously had had lumbar punctures. Backache of varying degree was invariably present, but although it was continuous it was never sufficient to put the child to bed. All, however, had been unable to run for some months and had been excused games at school. The backache was aggravated by straining and in some patients the pain radiated into one or both legs.

Examination showed a fixed lumbar spine which was either straight or only slightly lordotic, and hardly any movement occurred in any direction. Straight leg raising was always bilaterally restricted. The children tended to stand with one leg slightly flexed at the hip (Fig. 1), their gait was slow and, at the worst, shuffling. In some the skin in the middle of the lower lumbar region showed the stippled scars of multiple lumbar punctures. Only in one patient were there severe signs of nerve root compression, which amounted to weakness and

wasting in the thigh and leg muscles with absent knee and ankle jerks. One other child had quadriceps wasting and an absent knee jerk. One ankle jerk was absent in a third patient but the remaining three showed no neurological abnormality. Sensation was not impaired in any of our children, and bladder and bowel functioned normally. The clinical picture

FIG. 1

Case 1—A boy aged eight standing and attempting to touch his toes. Note the stance with the right thigh slightly flexed and wasted.

FIG. 2

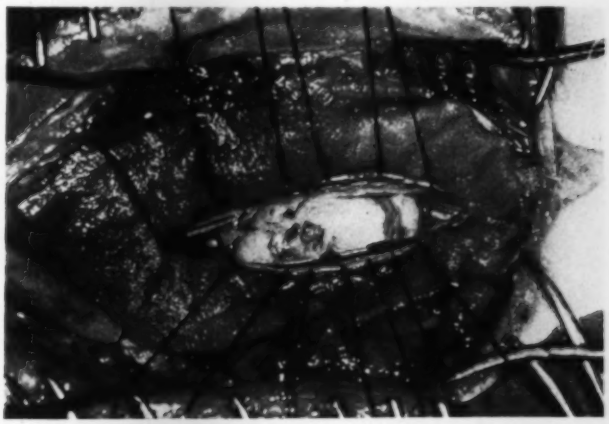


FIG. 3

Case 1. Figure 2—Myelograph showing the rounded superior limit of an epidermoid tumour at the level of the second lumbar vertebra. Figure 3—The appearance on opening the dura mater. There is pearly-white tumour filling the theca.

resembled tuberculous spondylitis, but the sedimentation rate was normal, as were the radiographs of the lumbar spine. The Mantoux reaction was positive in some, especially when the previous meningitis had been tuberculous. The protein of the cerebrospinal fluid was raised when a complete block was present and myelography demonstrated the rounded outline of one or more tumours in the lumbar region (Figs. 2 and 6).

FIG. 4

FIG. 5

Case 1. Figure 4—The excised tumour. (The scale is in centimetres.) Figure 5—Eighteen months after operation.

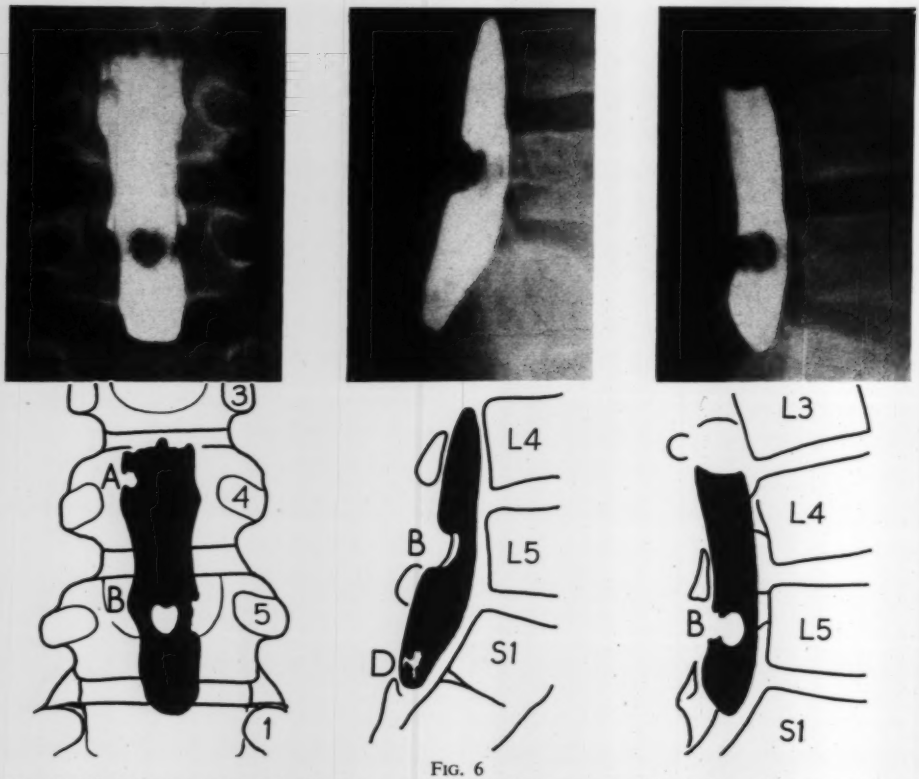


FIG. 6

Case 4—Three myelographs of the lumbar region showing four separate filling defects; three were due to epidermoid tumours and one to extruded debris. A—In relation to the left third lumbar nerve root. B—A central defect behind the fifth lumbar vertebra. C—Another rounded defect behind the lower border of the third lumbar vertebra. D—Faint shadow of extruded amorphous material behind the lower border of the first sacral vertebra.

Once the syndrome became known its recognition was simple, but our first cases presented puzzling problems both to ourselves and to those who referred them to us. The children were variously suspected to be suffering from ankylosing spondylitis, vertebral epiphysitis, tuberculous arachnoiditis and "functional disorder." After we had discussed our initial cases with colleagues, others were referred to us with the correct diagnosis.

FIG. 7

Case 4—The appearances on opening the dura. There were three separate epidermoid tumours and, on the extreme left, an extruded collection of debris.

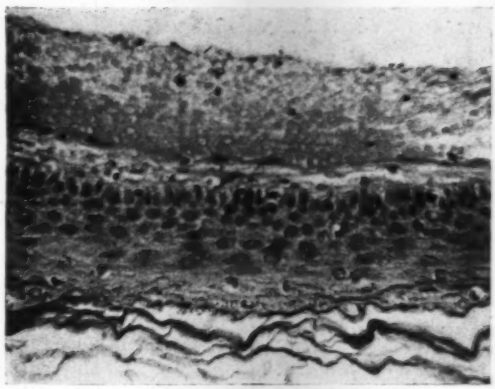


FIG. 8

A section of the wall of a rounded epidermoid tumour showing epithelial cells and amorphous material inside. (×150.)

We know of another patient, a girl aged six and a half with a history of four months' low back pain and gross restriction of all movements in the lumbar region (Dott 1960). At the age of five months she had been treated for meningococcal meningitis and received twenty-one lumbar punctures. At operation an intrathecal epidermoid tumour at the lumbar 3–4 level was removed and five months later she had regained a full range of spinal movements.

FINDINGS AT OPERATION

The tumour outline can be seen and palpated through the intact dura and when this has been opened the greyish white, pearly masses are found lying among the roots of the cauda equina (Fig. 3). Their diameter varies from a few millimetres to several centimetres

(Fig. 4). The thin capsule may be found to have ruptured spontaneously and the cheesy tumour contents may have accumulated below the main mass—these extruded collections present a typical myelographic appearance. Dura, arachnoid and nerve roots adhere to the tumours in varying degrees and the dissection of the tumour is rarely easy. The adhesions can be very dense and portions of the capsule may have to be left attached to nerve roots. It is possible that such remnants might again grow into tumours; their radical removal, however, could cause irreparable damage. Figure 7 shows the appearances on opening the dura of the patient whose myelograph is shown in Figure 6; there are three separate epidermoid tumours and on the extreme left an extruded collection of debris.

HISTOLOGY

The capsule consists of layers of epithelial cells surrounding amorphous debris which makes up the tumour mass. Neither blood vessels nor fibroblasts occur (Fig. 8).

RESULTS

In five of the children the course after operation was smooth and the spinal rigidity improved until the movements returned to normal within twelve to eighteen months (Fig. 5). Absent tendon reflexes did not recover. The one girl who had wasting and weakness of both legs before the operation was a great deal worse immediately afterwards. On the day after operation she had complete sensory loss from the fourth lumbar vertebra downwards and she could only flex the hips weakly. She had neither bowel nor bladder sensation and no sphincter control. The wound was reopened on the second post-operative day but no abnormality was found to account for the neurological disabilities. Normal sensation quickly returned to the legs and within a fortnight the quadriceps muscles had regained some power. Eighteen months after the operation she was seen at another hospital and her condition was reported to be that the bowel and bladder had returned to normal, there was normal quadriceps power but there had been no motor recovery in either leg below the knee. We are at a loss to account for the deterioration in the girl's condition.

DISCUSSION

We can find in the literature only five reports of lumbar epidermoid tumours in children which appear to be of congenital or spontaneous origin and not associated with other congenital defects. Dermoids and epidermoids grouped together comprise only between 0·3 and 1·8 per cent of tumours in the central nervous system, and according to Sachs and Horrax (1949), their incidence in the spine is only one-fourth of their incidence in the whole central nervous system.

The extreme rarity of epidermoid tumours of congenital origin contrasts sharply with the ability of Øeconomos and Caracalos (1957) to operate on and report ten patients in eighteen months, and of the authors to see and operate upon six within two years. This contrast suggests the etiological significance of lumbar puncture.

There are a number of reports of patients with congenital epidermoid tumours in the thoracic region (Critchley and Ferguson 1928, Rogers 1956, Tytus and Pennybacker 1956) but we are concerning ourselves in this paper with the lumbar region of patients under twenty-five years old.

Sachs and Horrax (1949) reviewed the literature and found sixty-one cases of dermoids and epidermoids in the spinal canal; of these fifteen were epidermoids, that is, they had no dermal elements in their structure; and out of these fifteen, only eight were in patients under twenty-five years old, and only three were in the lumbar region and were submitted to operation. These were reported by King (1939), Boldrey and Elvidge (1939) and List (1941). Tytus and

Pennybacker (1956) reported forty-one cases of " pearly " tumours, mostly from the Radcliffe Infirmary; seven of these were in the spinal canal but only two of them were epidermoids, one occurring at the level of the third thoracic vertebra in a man of thirty-two and the other in a girl of fifteen at the level of the first to third lumbar vertebrae, in whom operation was followed by a recurrence. Rand and Rand (1960) again reviewed the literature and reported their experiences of seventy-two cases of intraspinal tumours in children without any example of epidermoid tumours. They mentioned a report by Craig and Mitchell (1931) of a lumbar epidermoid tumour in a child without other congenital anomalies.

Table II summarises the features of those five patients with epidermoid tumours of the lumbar spine mentioned above, and it may be significant that one had a previous meningitis.

There can be little doubt that in our series and in the larger series of Øeconomos and Caracalos (1957) the epidermoid tumours had been growing throughout early childhood from epidermal cells implanted during lumbar puncture. In the Athens series these lumbar punctures were performed with a spinal-tap needle without a stilette. In our patients too

TABLE II

SUMMARY OF REPORTS OF PATIENTS UNDER TWENTY-FIVE YEARS OF AGE WITH SUPPOSED CONGENITAL LUMBAR INTRASPINAL EPIDERMOID TUMOURS WITHOUT DERMAL SINUSES, HYPERTRICHOSIS OR OTHER ANOMALY

Author	Age (*years*)	Sex	Site of tumour	History and physical signs	Previous history	Operation specimen and notes
Craig and Mitchell 1931	8	—	Thoracic 12–lumbar 1	3 years' history of stiffness and pain. Port-wine stain surrounding a dimple at lumbar 4 level	Given but not significant	Epidermoid 3·6 × 1·6 centimetres crushed on being handled and contained only amorphous material
King 1939	19	Male	Lumbar 4–5	2 years' history of pain in back and thighs. Right drop foot with sensory loss	Meningitis 6 years before	Epidermoid. Was in hospital 429 days and had six operations
Boldrey and Elvidge 1939	17	Male	Lumbar 2–4	Sciatica for several years, lumbar pain for 15 months, complete paralysis both legs	Not given	Epidermoid removed. (Operation in 1908)
List 1941	14	Male	Lumbar	7 months' history. Restricted straight leg raising. Absent ankle jerk	Not given	Epidermoid like a silkworm cocoon
Tytus and Pennybacker 1956	15	Female	Lumbar 1–3	Not reported. No spinal block but cerebrospinal fluid protein 1,000 milligrams/ 100 millilitres	Not given	Epidermoid, removal incomplete. Recurrence 4 to 5 years after operation but no recurrence at 8 years

we believe that this had been the common but not invariable practice—we cannot be sure that any of our patients had all their lumbar punctures performed with a needle and a stilette. Whilst all in the Greek series and four in ours had many punctures, our Case 5 had five and Case 1 only two, the smallest number recorded.

It seems that infants and children who contracted serious meningitis in the years 1948–51, when repeated intrathecal injections were practised, are the population at risk.

Gibson and Norris (1958) have shown that in 69 per cent of 300 punctures of normal skin a fragment is cut off and comes to lie within the lumen of the needle. These tests were carried out with bevelled intravenous needles between 18 and 24 British Wire Gauge. Needles with well fitting stilettes did not remove skin fragments. It is likely that skin fragments are quite often introduced into the subarachnoid space but their survival and proliferation must be very rare. The nutrition of the cells is probably similar to conditions of tissue culture and does not depend on a blood supply as Gibson and Norris expected.

SUMMARY

Six children who complained of pain and stiffness in the back had been treated with lumbar punctures between six and ten years before they came under observation. They were found to have intrathecal epidermoid tumours in the lumbar region which are presumed to have arisen from implanted skin fragments. The main evidence for this assumption is that since 1956 sixteen patients with lumbar epidermoid tumours in patients who had had previous lumbar punctures have been reported, in contrast to the five patients with lumbar epidermoid tumours recorded before that date. This suggests that there is an additional etiological factor.

ADDENDUM

Since this paper was submitted for publication there have been two further examples of this condition. A boy aged ten, who, at the age of nine months, had received treatment for tuberculosis of his left ankle and tuberculous meningitis in a fever hospital where he received eleven intrathecal injections of streptomycin, presented with a stiff back and no peripheral neurological signs. The myelograph was very like that shown in the paper, and at exploration a single pearly tumour was removed from the lumbar 2–4 area of the cauda equina. He made a complete recovery and within three months he could touch his toes.

We are indebted to our colleague, Mr G. A. Whitefield, for details of a patient under his care. The boy was aged ten when he presented with a stiff back and restricted straight leg raising. At the age of two he had received forty lumbar punctures in twenty days for tuberculous meningitis. The myelograph showed a filling defect and at operation a single tumour, epidermoid in nature, was removed from the lumbar 2–4 area. His spinal movements are returning.

We are indebted to our colleagues who referred cases to us. Our thanks are due to Mr J. Devlin and Mr G. Donald for photographic work and to Dr I. Leslie Steven for the operation photographs and the myelographs.

REFERENCES

BOLDREY, E. B., and ELVIDGE, A. R. (1939): Dermoid Cysts of the Vertebral Canal. *Annals of Surgery*, **110,** 273.

CHOREMIS C., ØECONOMOS, D., PAPADATOS, C., and GARGOULAS, A. (1956): Intraspinal Epidermoid Tumours in Patients Treated for Tuberculous Meningitis. *Lancet*, **ii,** 437.

CRAIG, J., and MITCHELL, A. (1931): Spinal Tumours in Childhood. *Archives of Diseases in Childhood*, **6,** 11.

CRITCHLEY, M., and FERGUSON, F. R. (1928): The Cerebrospinal Epidermoids (Cholesteatomata). *Brain*, **51,** 334.

DOTT, N. (1960): *Personal communication.*

GIBSON, T., and NORRIS, W. (1958): Skin Fragments Removed by Injection Needles. *Lancet*, **ii,** 983.

KING, J. E. J. (1939): Extradural Diploic and Intradural Epidermoid Tumors. *Annals of Surgery*, **109,** 649.

LIST, C. F. (1941): Intraspinal Epidermoids, Dermoids, and Dermal Sinuses. *Surgery, Gynecology and Obstetrics*, **73,** 525.

ØECONOMOS, D., and CARACALOS, A. (1957): Cholestéatomes intrarachidiens multiples complication tardive d'injections intrarachidiennes pour méningite tuberculeuse de l'enfance. *Revue Neurologique*, **97,** 81.

RAND, C. W., and REEVES, D. L. (1943): Dermoid and Epidermoid Tumors (Cholesteatomas) of the Central Nervous System. *Archives of Surgery*, **46,** 350.

RAND, R. W., and RAND, C. W. (1960): *Intraspinal Tumors of Childhood.* Springfield, Illinois: Charles C. Thomas.

ROGERS, Lambert (1956): Intraspinal Epidermoid Tumours. (Letters to the Editor), *Lancet*, **ii,** 519.

SACHS, E., Jun., and HORRAX, G. (1949): A Cervical and a Lumbar Pilonidal Sinus Communicating with Intraspinal Dermoids. *Journal of Neurosurgery*, **6,** 97.

TYTUS, J. S., and PENNYBACKER, J. (1956): Pearly Tumours in Relation to the Central Nervous System. *Journal of Neurology, Neurosurgery and Psychiatry*, **N.S. 19,** 241.

DISLOCATION OF THE PERONEAL TENDONS WITH MARGINAL FRACTURE OF THE LATERAL MALLEOLUS

SEPP MURR, ZÜRS, AUSTRIA

Forward displacement of the peroneal tendons from the groove behind the lateral malleolus is not an uncommon injury, but there have been few references to it in the English literature. A sudden strain at the moment when the muscles are tense causes tightening of the peroneal tendons which snaps the peroneal retinaculum and allows the tendons to dislocate from the groove behind the lateral malleolus. Bonnin (1950) suggested that the straining force occurred while the foot was plantar-flexed and everted; but Watson-Jones (1940) believed that the injury occurred from forced dorsiflexion of the ankle, and he reported an operation to prevent recurrent dislocation of the tendons by deepening the groove behind the malleolus.

The injury is often sustained while ski-ing. In the winter of 1958 I treated seven patients with acute dislocation of the peroneal tendons; and there can be no doubt that it occurs from forced dorsiflexion of the ankle joint. The ski-tip dives in and becomes fixed in the snow, the patient being thrown forwards.

The first report of this injury was by Allen in 1895 in the *British Medical Journal*, in which he reported successful treatment by strapping the ankle for three weeks. Jones (1932) described a method of repair by operation, but conservative treatment by immobilisation in adhesive strapping or plaster was accepted by Watson-Jones (1940), Hauser (1950) and Whitman (1930). Muralt (1956) advised operative repair in recurrent cases.

This paper records three patients in whom forward dislocation of the peroneal tendons occurred with marginal fractures of the lateral malleolus. No report of this condition has been found in the literature over the past thirty years.

CASE REPORTS

Case 1—A man aged thirty, in good general health, was unable to walk because of pain in his right ankle which he had injured in a manner probably similar to that described above. Clinical examination showed considerable swelling of the right lateral malleolus, which was tender, and over which a loose piece of bone could be felt and moved under the skin. There was tenderness over the calcaneo-fibular ligament, in which pain was produced on forcibly inverting the foot.

The radiograph (Fig. 1) showed quite clearly that a small chip of bone had been broken off the lateral malleolus, with two smaller flakes lying below and between the tip of the lateral malleolus and the talus.

At this stage the diagnosis appeared to be one of torn ligaments with flake fractures; but further clinical examination revealed—not without difficulty—that the peroneal tendons were dislocated forwards and that they were lying in front of the loose chip of bone.

Reduction of both the peroneal tendons and the loose chip of bone was easy, but not stable; the tendons snapped back to the dislocated position immediately the pressure of the fingers was withdrawn, and the fragment of bone, although freely mobile, would not stay in what appeared to be its anatomical position.

Operation—Under local anaesthesia a straight incision was made over the lower fibula and lateral malleolus. A large haematoma was cleared from around the peroneal tendons to reveal that the fractured chip of bone—one to one and a half centimetres in length—was in fact the anterior rim of the groove on the posterior surface of the lateral malleolus in which the peroneal tendons are normally contained. Posteriorly the chip was still attached to the peroneal retinaculum

and, opening like a door, had allowed the peroneal tendons to lie between the raw surfaces of the chip of bone and the lateral malleolus. The peroneal tendons were held reduced while the chip was sutured into place after suitable drill holes had been made in both it and the lateral malleolus, after which bone and tendons appeared stable. The calcaneo-fibular ligament was repaired (Fig. 2).

FIG. 1

FIG. 2

Case 1. Figure 1—Before operation. Figure 2—After operation.

FIG. 3

FIG. 4

Figure 3—Case 2. Figure 4—Case 3.

Other cases—Subsequently during the same season two other patients were seen. Case 2 was like Case 1 (Fig. 3), but in Case 3 the patient sustained a bimalleolar fracture (Fig. 4). It was not until seven weeks later, when the patient was walking out of plaster and with the fracture united, that she complained of pain over the lateral malleolus, worse on inversion. Examination gave the same findings as before, with the loose flake of bone and the dislocated tendons. Operation was performed successfully as in the other two cases.

Results—All three patients returned to ski-ing and have remained free of symptoms. The patient in Case 1 was seen a year after operation and had no residual symptoms, no swelling and no limitation of ankle movements.

DISCUSSION

This condition could easily be misdiagnosed as a sprained ankle, especially if there were some delay with swelling of the lateral malleolus and if the significance of the radiographic changes were not appreciated.

Once the diagnosis is made operation is indicated because it is simple, quick and reliable. Conservative treatment does not appear possible and should not be attempted, because there is no way in which the peroneal tendons can be held reduced while the fracture unites.

SUMMARY

1. Three patients are described in whom forward dislocation of the peroneal tendons was associated with a chip fracture of the lateral malleolus and forward dislocation of the tendons through the fracture.
2. This injury differs from the more usual simple anterior dislocation of the peroneal tendons in which rupture of the superior peroneal retinaculum allows the dislocation to occur.
3. A simple operation is described which succeeded in holding reduced the dislocated tendons by suturing the fractured small chip of bone back to the lateral malleolus.

Since this paper was submitted six further patients with this condition have been seen, four of whom have been operated upon. It is too early yet to give the results in these cases.

REFERENCES

ALLARIA, A., and FRANZ, A. (1953): La lussazione traumatica dei tendini dei muscoli peronei laterali. *Minerva Ortopedica*, **4**, 203.

ALLEN, W. (1895): Dislocation of Peroneus Longus Tendon. *British Medical Journal*, **ii**, 1,161.

BONNIN, J. G. (1950): *Injuries to the Ankle*. London: William Heinemann Medical Books Ltd.

BRAGARD, K. (1934): Bandage gegen Luxation der Peronealsehnen. *Münchener Medizinische Wochenschrift*, **81**, 2,008.

HAUSER, E. D. W. (1950): *Diseases of the Foot*. Second edition. Philadelphia and London: W. B. Saunders Company.

JONES, E. (1932): Operative Treatment for Chronic Dislocation of the Peroneal Tendons. *Journal of Bone and Joint Surgery*, **14**, 574.

LOHE, R. (1934): Die gewohnheitsmässige Peronealsehnenluxation und ihre operative Beseitigung. *Zentralblatt für Chirurgie*, **61**, 1,154.

MURALT, R. H. v. (1956): Luxation der Peronäalsehnen. *Zeitschrift für Orthopädie*, **87**, 263.

RICHARD, M. (1930): Über Sehnenluxationen. *Deutsche Zeitschrift für Chirurgie*, **226**, 156.

ROMANUS, R. (1947): Luxatio tendinum peroneorum. *Nordisk Medicin*, **36**, 2,407.

SCHILDT, E. (1947): Luxatio tendinum peroneorum. *Nordisk Medicin*, **34**, 837.

VOLKMANN, J. (1937): Zur Pathologie und Behandlung der Peroneussehnenluxation. *Archiv für Orthopädische und Unfall-Chirurgie*, **38**, 262.

WATSON-JONES, R. (1940): *Fractures and Other Bone and Joint Injuries*. Edinburgh: E. & S. Livingstone.

WHITMAN, R. (1930): *A Treatise on Orthopaedic Surgery*. Ninth edition. London: Henry Kimpton.

A RADIOLOGICAL APPROACH TO THE SUBTALAR JOINT

IAN ISHERWOOD, MANCHESTER, ENGLAND

From the Department of Radiology, Manchester Royal Infirmary

The subtalar joint is complex, and its radiological abnormalities are often overlooked because their demonstration presents technical difficulties.

Inversion and eversion are generally thought to be carried out at the transverse joint of the foot, but it is at the talo-calcaneo-navicular joint that most of these movements occur (Wood Jones 1949). Active movements at this level are usually combined with ankle movement. Hence inversion, adduction and flexion occur together as do eversion, abduction and extension. " Movement of the calcaneum under the talus is essential to inversion and eversion and fixation of the calcaneum will for all practicable purposes prevent these movements." (Inkster 1938.) Abnormalities of this region, whether congenital or acquired, have therefore a considerable effect on the function and mobility of the foot.

FIG. 1

A drawing of the upper surface of the calcaneum. The three joint facets of the calcaneum and the sulcus calcanei are demonstrated.

The object of this paper is to suggest a radiographic approach to the demonstration of this region, illustrated by examples of the abnormalities exposed.

ANATOMY

The subtalar joint is formed by three separated sets of facets on the calcaneum and plantar surface of the talus. These may be termed the anterior, middle and posterior joints (Fig. 1). The anterior and middle joints are frequently separated by an inter-articular ligament (Smith 1894).

The posterior joint has its long axis set obliquely at about 40 degrees to the mid-line of the foot. Its contour is complex but generally curved convexly upwards. The anterior and middle joint facets of the calcaneum have the same direction and relation to the axis of the foot, but their curvature tends to be concave.

Across the contiguous surfaces of the calcaneum and talus are grooves—the sulcus calcanei and sulcus tali—which complete the canalis tarsi. This tunnel opens at its anterior end into the wide bay of the sinus tarsi. The canal is occupied by fat and small vessels. The interosseous talo-calcaneal ligament occupies the sinus tarsi and represents a strong axis about which gliding movements may occur.

RADIOGRAPHY

To establish a logical radiographic approach to a joint of this complexity obviously involves multiple projections. Several projections have been suggested by previous authors, particularly for injuries of the calcaneum.

Palmer (1948) commented on the difficulties of demonstration and suggested an oblique lateral view from below and posteriorly to give a clear view of the posterior facet as it reaches the end of the sinus tarsi. Slomann (1926) and Holland (1928) had previously emphasised

the importance of an oblique lateral view in the diagnosis of calcaneo-navicular coalition. An oblique view is standard procedure in some centres (Chambers 1950).

Anthonsen (1943) described an oblique projection highly commended by Warrick and Bremner (1953) for its value in demonstrating the posterior and middle facets. The technique for this projection involves two tube tilts, 25 degrees caudally and 30 degrees dorsi-ventrally towards the toes, the central ray being directed to a point just below the medial malleolus with the dorsiflexed foot in the lateral position on the film. It has not been found possible

FIG. 2

FIG. 3

FIG. 4

Normal subtalar joint. Figure 2—Oblique lateral projection. Figure 3—Medial oblique axial projection. Figure 4—Lateral oblique axial projection. Radiographic factors are given on page 568.

to produce these tilts together on many x-ray tubes. The foot position can be adjusted to counter this, but it is felt that the double angulation together with foot positioning makes comparative reproduction difficult. The middle joint facet is also at its greatest distance from the film.

Several oblique medial and oblique lateral projections were suggested by Clark (1956) in an attempt to demonstrate the joint facets. She suggested that the limb be rotated medially

45 degrees and the tube tilted 40 degrees, 30 degrees or 10 degrees. Alternatively, the limb may be rotated laterally 45 degrees with a tube tilt of 12 to 18 degrees.

In a busy orthopaedic department also undertaking accident work it is of value to have available a routine procedure that can be applied to both static and traumatic lesions arising at the subtalar joint. It should be a method applicable to immobilised patients and to painful stiff feet. It should also be a method which can be used with any x-ray tube and with as little wastage of time as possible. An attempt has been made to establish an economic method of demonstrating all sections of the subtalar joint.

A disarticulated skeleton foot with foam rubber between the talus and calcaneum to establish a resilient joint space was radiographed. Wire markers were fixed in turn to the oval periphery of all three facets of the calcaneum. The most advantageous method of viewing a joint is with its contiguous articular surfaces in profile. The central ray was therefore directed tangentially to each joint. The superimposition of the opposite margins of the oval marker on the film confirmed the profile projection of the joint. Since the posterior joint has a complex curved surface it is advantageous to obtain two views of it at right angles. Radiographs of the disarticulated foot with wire markers in position were also obtained in all the projections described by previous authors. By this experimental technique the following projections are put forward as an approach to the subtalar joint.

Oblique dorso-plantar (oblique lateral) to demonstrate the anterior joint (Fig. 2). The inner border of the foot is placed on the film and the sole inclined 45 degrees to the film. The tube is centred 1 inch below and 1 inch anterior to the lateral malleolus.

Medial oblique axial to demonstrate the middle joint and also to give a tangential view of the convexity of the posterior joint (Fig. 3). The foot is dorsiflexed and when possible inverted, the position being maintained by a broad bandage held by the seated patient. The limb is rotated medially 60 degrees and the foot rested on a 30 degrees wedge. The tube is directed axially, tilted 10 degrees towards the head and centred 1 inch below and 1 inch anterior to the lateral malleolus. Inversion, which completes the composite movement of inversion, adduction and flexion, can be maintained by an asymmetrical pull on the broad bandage. This projection gives an " end-on " view of the canalis tarsi as in Anthonsen's view but has the added advantages of placing the sustentaculum tali close to the film for bone detail and of being easily reproduced by a fixed angulation of the tube (see below).

Lateral oblique axial to demonstrate the posterior joint in profile (Fig. 4). The foot is dorsiflexed and when possible everted, the position again being maintained by asymmetrical pull on the broad bandage. The limb is laterally rotated 60 degrees, flexing the knee when necessary, and the foot rested on a 30 degrees wedge. The tube is directed axially, tilted 10 degrees towards the head and centred 1 inch below the medial malleolus. The tube direction and tilt may be fixed for both oblique axial views. The radiographic factors used are 60–65 kilovolts and 50 mAs, at 36 inches using Ilfex non-screen film. Standard views of the tarsus in lateral and axial projections may be necessary to demonstrate the tuber-joint angle or other features but it is suggested that when interest is directed to the subtalar joint the projections described above should be routine.

Multiplane tomography and stereoscopy have been investigated to a limited extent and have potentialities.

ABNORMALITIES OF THE SUBTALAR JOINT

The following abnormalities have been demonstrated by oblique views when standard projections were inadequate.

Congenital abnormalities—Two groups of structural anomalies which may produce a "peroneal spastic flat foot " have a direct relation to the subtalar joint.

Talo-calcaneal bridge—The bridge may be osseous, cartilaginous or fibrous, uniting the posterior aspect of the sustentaculum tali with the talus. Movement of the joint is impeded

and inversion is impossible. Symptoms often do not occur until adolescence, but early diagnosis is valuable because late sequelae may be reduced. The bony bar may be demonstrated in the medial oblique axial view. Narrowing of the middle joint space is also usually present and may be the only feature when the fusion is cartilaginous (Fig. 5).

FIG. 5

Talo-calcaneal bridge. The bridge demonstrated in the medial oblique axial view unites the posterior aspect of the middle joint with the talus. The joint space is narrowed.

FIG. 6

Calcaneo-navicular bridge. A pseudarthrosis is present in the calcaneo-navicular bridge, demonstrated in the oblique lateral view.

Calcaneo-navicular bridge—A similar type of fusion may occur due probably to similar developmental factors in the early differentiation of mesenchyme. A pseudarthrosis may develop. Symptoms of this coalition are often found earlier, because, it is thought, the mid-tarsal joint is more vulnerable to stress than the subtalar joint in childhood (Jack 1954). This fusion is best seen in the oblique lateral view (Fig. 6).

It has been suggested that many feet show some degree of valgus deformity and that the presence of these anomalies has been overlooked because of the difficulty of visualisation on

routine radiographs (Webster and Roberts 1951, Harris 1955). Spur formation on the dorso-lateral aspect of the head of the talus has been considered significant of the presence of congenital anomalies (Harris and Beath 1948). It has been described by some authorities including Jack (1954), however, as representing the effects of long standing valgus deformity at the midtarsal joint of whatever origin. It is to be emphasised therefore that this sign when

FIG. 7

Spur formation on the dorso-lateral surface of the talus seen in the standard lateral projection. A subsequent medial oblique axial radiograph demonstrated a talo-calcaneal bridge.

FIG. 8

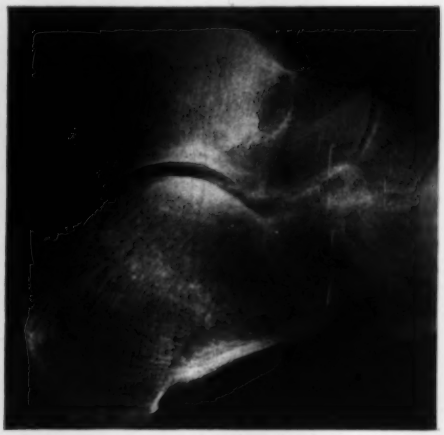


FIG. 9

Fracture of the calcaneum. Figures 8 and 9—The medial oblique axial and the lateral oblique axial demonstrate the subtalar joint to be intact.

seen in a routine view of the foot is an indication for further investigation of the subtalar joint (Fig. 7).

Extra-articular arthrodesis of the subtalar joint by introducing bone grafts into the sinus tarsi has been employed in the correction of some cases of paralytic flat foot (Grice 1952). Maintenance of the graft in position post-operatively as an effective block to eversion is essential. The medial oblique axial view is valuable for confirming this and may be employed while the foot is still in plaster.

Traumatic lesions—Fractures of the calcaneum may be simple crack fractures (Figs. 8 and 9) or may involve the subtalar joint, particularly in the shearing compression type of fracture. Warrick and Bremner (1953) emphasised the importance of identifying the position of the lateral portion of the posterior articular facet which may be depressed into the main lateral fragment of the calcaneum by secondary compression when the fracture runs obliquely across

FIG. 10

Fracture of the calcaneum. Depression of the posterior articular facet with a horizontal split of the tuberosity demonstrated by the medial oblique axial view.

FIG. 11

Tuberculosis of the subtalar joint. Involvement of the anterior compartment demonstrated by the oblique lateral view (note involvement of the calcaneo-cuboid joint). Oblique axial views showed the remainder of the subtalar joint to be relatively spared.

the posterior facet. The facet may be depressed with the underlying bone or the depressed lateral portion may be continuous with the tuberosity which is split horizontally. These features can be demonstrated by the medial and lateral oblique axial views (Fig. 10).

Many fractures of the calcaneum with severe joint involvement may lead to bony ankylosis with varying functional disability. It seems to be of some importance prognostically,

however, to demonstrate any joint involvement because degenerative change may frequently be anticipated when the articular margins have been disrupted. Traumatic arthritis may be severe (Fig. 14).

Arthritis. *Tuberculous arthritis* (Fig. 11)—In tuberculous arthritis complete disorganisation may be produced but in the early stages the infection may be limited to part of the joint and

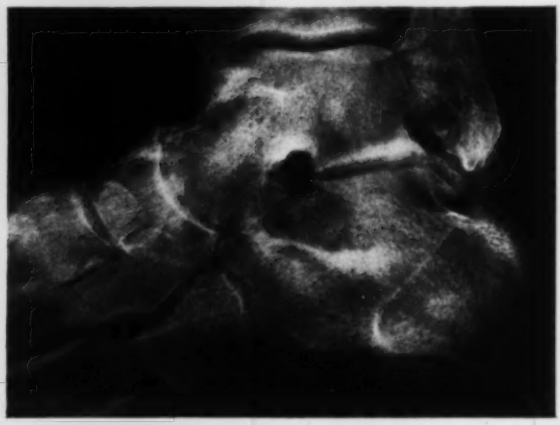


FIG. 12

Gout of the subtalar joint. Involvement of the middle compartment demonstrated in the medial oblique axial projection.

FIG. 13

Rheumatoid arthritis. Almost complete loss of joint space in the middle compartment of the subtalar joint is demonstrated by the medial oblique axial view. The posterior compartment is relatively spared. (Note involvement of the talo-navicular joint.)

be demonstrable by oblique views. Clinical differentiation at this stage may be difficult. *Gout* (Fig. 12)—Urate deposits in gout may be demonstrated in relation to the subtalar joint before any major arthritic change has developed. *Rheumatoid arthritis* (Fig. 13)—Although mainly involving the small joints distally, rheumatoid arthritis may produce a rigid valgus deformity by involvement of the subtalar joint. Standard views are usually confined to the

forefoot and early proximal changes may be overlooked. Erosions and joint space narrowing are demonstrable. *Osteoarthritis* (Fig. 14)—Osteoarthritis in the subtalar joint may be secondary to structural deformity or to trauma. It is capable of producing a stiff and painful foot. Early narrowing of the joint space is often confined to one or two compartments of the joint and will therefore be seen clearly only in oblique axial views.

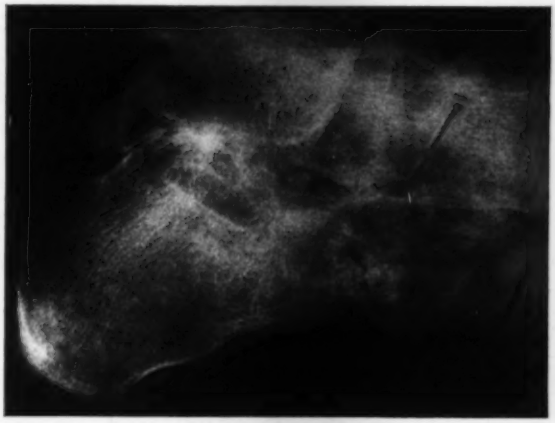


FIG. 14

Gross osteoarthritis after injury. Several tarsal joints are involved, particularly the posterior compartment of the subtalar joint demonstrated in the lateral oblique axial projection.

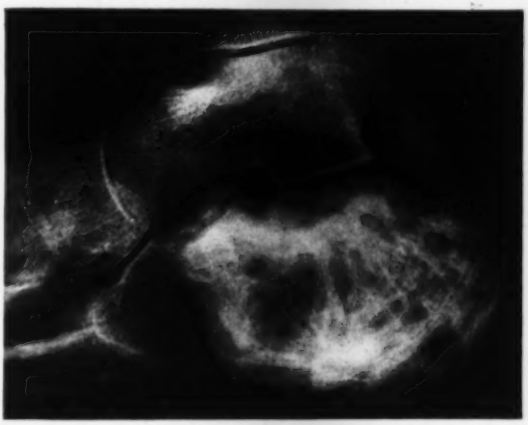


FIG. 15

Osteitis deformans of the calcaneum. Secondary narrowing in the middle compartment of the subtalar joint, demonstrated in the medial oblique axial projection.

Local bone disease—Many other conditions, primarily affecting bone, may produce secondary change in the subtalar joint—for example, osteitis deformans (Fig. 15).

SUMMARY

The subtalar joint is not easy to visualise by standard radiographic methods. Several projections are described including medial and lateral oblique axial views to demonstrate the

three compartments of the joint. It is suggested that when visualisation of the subtalar joint is required these views should be routine.

Various conditions affecting the subtalar joint and their demonstration by these oblique axial views are discussed.

I should like to thank Dr E. Duff Gray, Director of the Department of Radiology, and Mr D. Lloyd Griffiths, Director of the Department of Orthopaedic Surgery, Manchester Royal Infirmary, for their valuable advice and encouragement. I am indebted to Dr R. G. W. Ollerenshaw and the Department of Medical Illustration of the Manchester Royal Infirmary for the preparation of the prints, and to Mr R. A. H. Neave for the drawing in Figure 1. I should also like to acknowledge the enthusiastic cooperation of Miss E. McRae, Senior Radiographer in the Orthopaedic X-ray Department.

REFERENCES

ANTHONSEN, W. (1943): An Oblique Projection for Roentgen Examination of the Talo-calcanean Joint, Particularly Regarding Intra-articular Fracture of the Calcaneus. *Acta Radiologica*, **24,** 306.

BREMNER, A. E., and WARRICK, C. K. (1951): Fractures of the Calcaneus. *Journal of the Faculty of Radiologists*, **2,** 235.

CHAMBERS, C. H. (1950): Congenital Anomalies of the Tarsal Navicular. *British Journal of Radiology*, **N.S. 23,** 580.

CLARK, K. C. (1956): *Positioning in Radiography*. Seventh edition. Ilford Limited. London: Wm. Heinemann (Medical Books) Ltd.

GRICE, D. S. (1952): An Extra-articular Arthrodesis of the Subastragalar Joint for Correction of Paralytic Flat Feet in Children. *Journal of Bone and Joint Surgery*, **34–A,** 927.

HARRIS, R. I. (1955): Rigid Valgus Foot due to Talocalcaneal Bridge. *Journal of Bone and Joint Surgery*, **37–A,** 169.

HARRIS, R. I., and BEATH, T. (1948): Etiology of Peroneal Spastic Flat Foot. *Journal of Bone and Joint Surgery*, **30–B,** 624.

HOLLAND, C. Thurstan (1928): The Accessory Bones of the Foot. In *The Robert Jones Birthday Volume*, p. 157. London: Humphry Milford Oxford University Press.

INKSTER, R. G. (1938): Inversion and Eversion of the Foot and the Transverse Tarsal Joint. *Journal of Anatomy*, **72,** 612.

JACK, E. A. (1954): Bone Anomalies of the Tarsus in Relation to " Peroneal Spastic Flat Foot." *Journal of Bone and Joint Surgery*, **36–B,** 530.

JONES, F. Wood (1949): *Structure and Function as Seen in the Foot*. Second edition. London: Baillière, Tindall and Cox.

PALMER, I. (1948): The Mechanism and Treatment of Fractures of the Calcaneus. *Journal of Bone and Joint Surgery*, **30–A,** 2.

SLOMANN, H. C. (1926): On the Demonstration and Analysis of Calcaneo-Navicular Coalition by Roentgen Examination. *Acta Radiologica*, **5,** 304.

SMITH, E. Barclay (1894): The Astragalo-Calcaneo-Navicular Joint. *Journal of Anatomy and Physiology*, **30,** 390.

WARRICK, C. K., and BREMNER, A. E. (1953): Fractures of the Calcaneum. *Journal of Bone and Joint Surgery*, **35–B,** 33.

WEBSTER, F. S., and ROBERTS, W. M. (1951): Tarsal Anomalies and Peroneal Spastic Flatfoot. *Journal of the American Medical Association*. **146,** 1,099.

A CASE OF LUMBAR OSTEOCHONDRITIS FROM THE BRONZE AGE

CALVIN WELLS, NORWICH, ENGLAND

I was recently making an anthropological examination of skeletal remains from a complicated Bronze Age round barrow at Long Crichel, Dorset. In Grinsell's standard numeration of barrows it is Long Crichel No. 5.

The barrow contained several inhumations and cremations. One of the inhumations which dates from about 1600 B.C. is that of an adolescent girl aged sixteen. The skeleton is substantially complete and in good condition. The most noteworthy feature about it is an area of deficient bone on the antero-superior margin of the bodies of the third and fourth lumbar vertebrae (Figs. 1 and 2). In each case about one-third of the mid-line depth of the vertebral body is lacking. The condition extends posteriorly across the vertebrae for about two-fifths of their antero-posterior depth, the total deficient mass being wedge-shaped. A low, raised, limiting margin of bone is present on the ventral surfaces of the vertebrae immediately below the defective area.

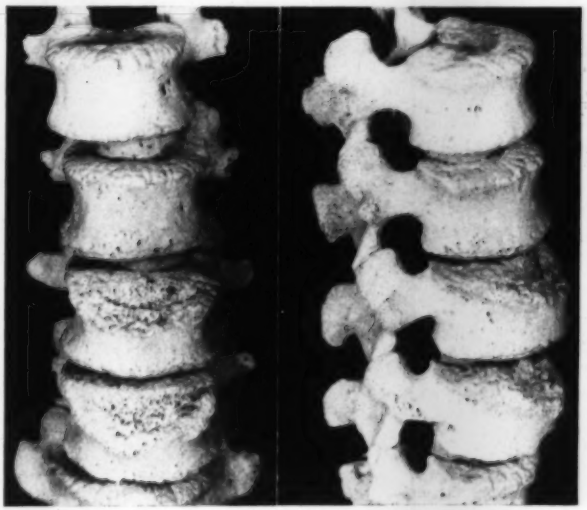


FIG. 1
Photographs of the specimen.

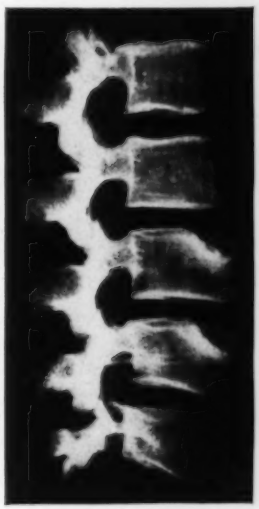


FIG. 2
Lateral radiograph.

This condition is an undoubted case of adolescent osteochondritis. It is well known radiologically but dried specimens are rarely encountered. The present example appears to be the first recognised as such from archaeological material of this date. For the purposes of photography the bones were assembled with small discs of cork between them.

No other characteristics of special note were found in this body. Large squatting facets were present on the distal articular surfaces of both tibiae and on the necks of the tali, but these are regular features in material of this period.

My thanks are due to Mr Charles Green, the excavator, and to the Ministry of Works for permission to publish this account.

THE STRUCTURE AND FUNCTION OF THE PROXIMAL END OF THE FEMUR

R. S. GARDEN, PRESTON, ENGLAND

From the Orthopaedic Department, Preston Royal Infirmary

The familiar outline of the proximal end of the femur is characterised by its almost spherical head, slightly flattened neck and two trochanters with their communicating intertrochanteric ridge (Fig. 1). Frontal section of the uppermost third of the femur shows the powerful cortex and fragile medulla of the shaft (Fig. 2). Above the lesser trochanter this arrangement is reversed, and a thin cortical shell clothes the dense arrangement of cancellous bone which forms the internal weight-bearing system in the neck and head (Fig. 3).

INTERNAL WEIGHT-BEARING SYSTEM

The calcar femorale, or as Bigelow (1900) described it " the true neck of the femur," is a vertical plate of bone lying deep to the lesser trochanter. The calcar forms the distal anchorage of the medial arrangement of trabeculae in the internal weight-bearing system, sometimes known as the compression group, which streams upwards to end fan-wise at the articular margin of the head. The lateral arrangement of trabeculae, sometimes known as the tension group, arises from the lateral femoral cortex and curves upwards and medially to merge with the compression group in the femoral head. A third group of trabeculae springs from the medial aspect of the cortex at the level of the lesser trochanter to decussate with the lateral trabeculae at the junction of neck and shaft. Enclosed within these trabecular systems is the area of lessened density known as Ward's triangle.

This interpretation of the internal weight-bearing system derives largely from Ward (1838) and from the radiographic appearance of the femoral neck and head which Ward's diagram so well foresaw (Fig. 4). However, both diagram and radiograph fail to demonstrate the three-dimensional features of the proximal end of the femur, and for this reason the above descriptions of the calcar femorale and internal weight-bearing system are inadequate.

The femoral neck inclines upon the shaft at an angle of about 127 degrees, ranging normally between 113 and 136 degrees (Humphry 1888). The neck is also set upon the shaft at an angle varying from 38 degrees anteversion to 20 degrees retroversion, but which is usually in the region of 10 degrees anteversion (Kingsley and Olmsted 1948). In the opposite direction the neck itself shows a slight curvature with its convexity directed forwards (Walmsley 1915). This twisting and turning presumably represents the developmental response of the femur to the upright position which demands conversion of the weight-bearing stresses from an oblique to a vertical direction. It also suggests that, in basic outline, *the proximal end of the femur is striving towards a spiral form.* It is hoped to show that this observation provides the key to a better understanding of the internal weight-bearing system.

By stereo-radiography the calcar femorale and medial trabeculae of the internal weight-bearing system are seen to be an upward and spiral continuation of the postero-medial cortex of the shaft, and the lateral trabeculae an expanded and rotated continuation of the antero-lateral cortex. The medial group of trabeculae occupies a postero-inferior and the lateral group an antero-superior position in the femoral neck. This description may be clarified by the following experiment in which a tube of multiple parallel wires is mounted on a wax former to represent the radio-opaque Haversian systems with their concentric lamellae on which the radiological appearance of the femoral shaft depends (Fig. 5). The spiral conformation of the proximal end of the femur suggests that its peculiar angulation has

FIG. 1

FIG. 2

Figure 1—The posterior aspect of the proximal end of the femur. Figure 2—Frontal section of the upper third of the femur to show preponderance of cortical bone in the shaft and of cancellous bone in the neck and head.

FIG. 3

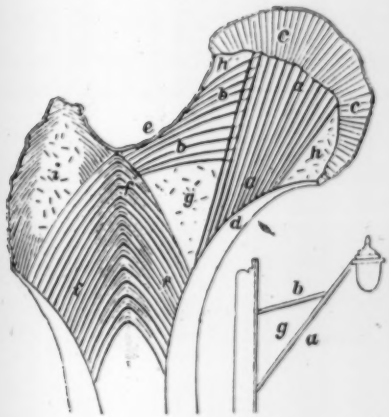


FIG. 4

Figure 3—Internal weight-bearing system in the femoral neck. M—medial system of lamellae; L—lateral system of lamellae; W—Ward's triangle; and I—intertrochanteric arch. Figure 4—Diagram from *Outlines of Human Osteology*, F. O. Ward, 1838, for comparison with radiographic appearances. (Reproduced by permission of the Editor, *Journal of Bone and Joint Surgery*, American volume.)

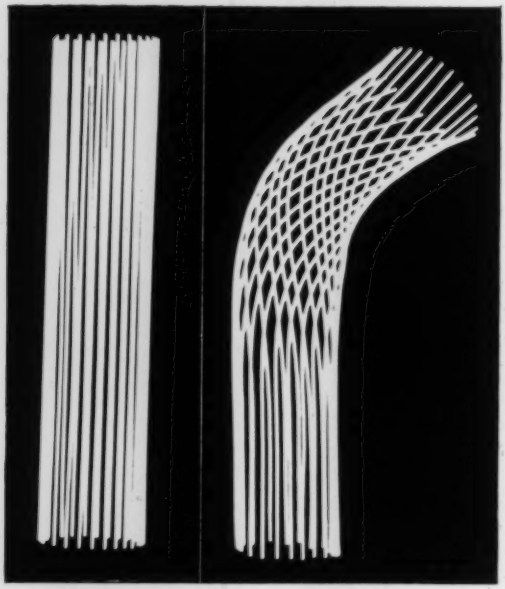


FIG. 5 FIG. 6

Figure 5—Radiograph of tube of parallel wires. Note appearance of "cortex" where wires are superimposed. Figure 6—Disposition of wires after twisting tube to show their similarity to the pattern of the medial and lateral lamellae in the internal weight-bearing system.

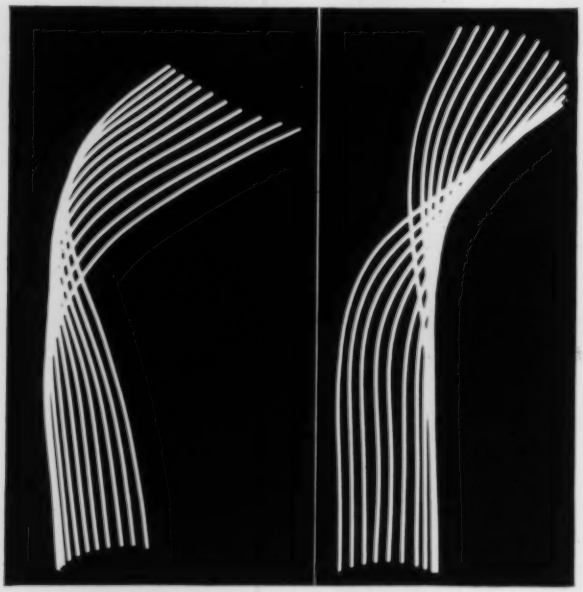


FIG. 7 FIG. 8

Wire model bisected in the line of its spiral. Figure 7—Horizontally arching disposition of the wires in the antero-lateral half. Figure 8—Vertical disposition of the wires in the postero-medial half.

been achieved developmentally by simple twisting of the original shaft in an inward, forward and then backward direction. Similar twisting of the tube of parallel wires is found, in practice, to produce a radiographic shadow closely resembling the trabecular pattern of the internal weight-bearing system (Fig. 6). Bisection of the wire model in the line of its spiral into antero-lateral and postero-medial halves is then found to present a horizontally arching

FIG. 9

Removal of anterior wall of upper end of femur to show antero-medial group of lamellae extending outwards as expanded continuation of intertrochanteric line. Arrow indicates inferior tubercle of the neck and direction of intertrochanteric line.

FIG. 10

Appearance of the calcar femorale on posterior dissection. Removal of the posterior cortical shell results in partial removal of the calcar itself, and creates the illusion of a spur projecting into the femoral metaphysis. F—calcar femorale; L.T.—lesser trochanter. (From M. Harty (1957): The Calcar Femorale and the Femoral Neck. Reproduced by courtesy of Dr Harty, and by permission of the Editor, *Journal of Bone and Joint Surgery*, American volume.)

disposition in the antero-lateral half and a near-vertical disposition of the wires in the postero-medial half (Figs. 7 and 8). Parallel wires have been chosen for the sake of clarity although their use is strictly incorrect, since the Haversian systems orientated along the lines of stress (Benninghoff 1925) are diagonally disposed to the long axis of the femur (Harris and Cohen 1957).

Further examination shows that the third group of trabeculae which decussates with the lateral group in the intertrochanteric region is centred upon a lamellar expansion of the thickened ridge in the femoral cortex known as the anterior intertrochanteric line (Fig. 9). A small area in the anterior wall of the neck, the posterior wall of the neck and the two trochanters with their communicating ridge are seen to be devoid of specialised trabeculae. Ward's triangle therefore represents a central area where trabecular reinforcement is absent in the medulla and in both anterior and posterior walls of the neck.

The calcar femorale is usually displayed by removal of the posterior cortical shell of the upper femoral metaphysis. This dissection results in partial removal of the calcar itself which then appears as an isolated plate or spur projecting into the metaphysis (Fig. 10). Removal of the cancellous tissue in the femoral neck after bisection of the femur through the lesser

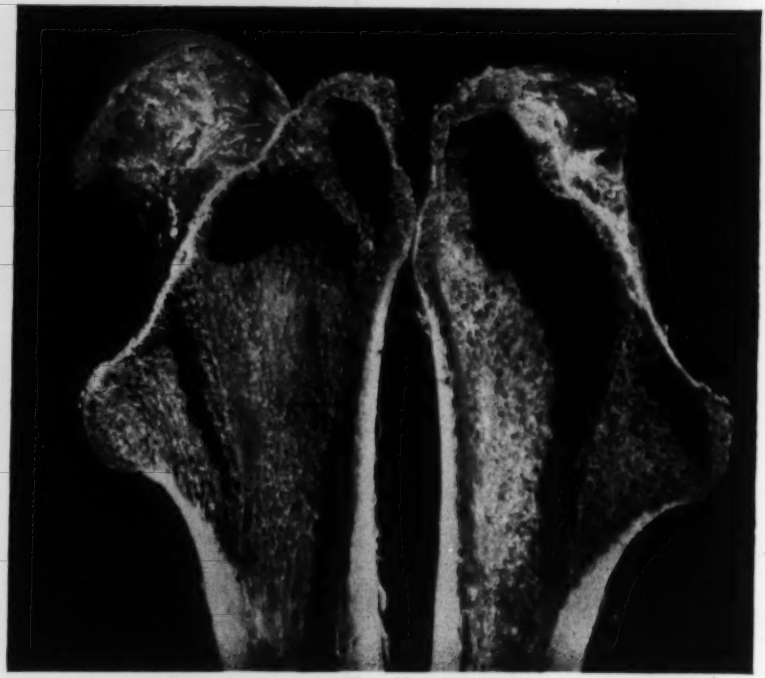


FIG. 11

Bisection of the femur through level of lesser trochanter to illustrate true nature of calcar femorale as the uninterrupted continuation of the postero-medial cortex on which the lesser trochanter is based.

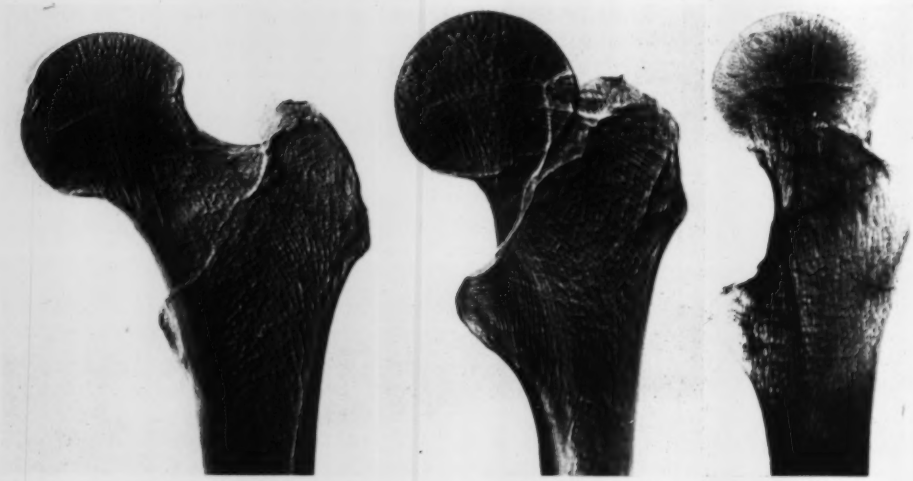


FIG. 12 FIG. 13 FIG. 14

Serial radiographs of the calcar femorale showing its laminar structure. Figure 12—Antero-posterior view. Figure 13—Oblique view. Figure 14—Lateral view.

trochanter, however, reveals the calcar as an uninterrupted laminar sheet of almost cortical hardness lying in continuity with the postero-medial cortex and overlain by the lesser trochanter (Fig. 11). The laminar structure of the calcar is demonstrated by serial radiography in different degrees of rotation (Figs. 12 to 14), and by every radiograph of a displaced subcapital fracture of the femur (Fig. 15).

FIG. 15

Displaced subcapital fracture of the femur to demonstrate laminar nature of the calcar femorale. With lateral rotation of the distal fragment the calcar "disappears" and is replaced by a series of longitudinal trabeculations which are, in effect, the laminae of the calcar itself presented in 90 degrees rotation.

The weight-bearing capacity and therefore the total amount of bone required in the femoral metaphysis need obviously be no greater than in the diaphysis. Expansion of the upper end of the femur has thus been achieved simply by a splitting-off or lamination of the closely packed lamellae of the shaft (Figs. 16 and 17). Hirsch and Brodetti (1956) have shown that the combined cortical and cancellous layers in both superior and inferior aspects of the femoral neck are each responsible for 50 per cent of its weight-bearing capacity, and Tobin (1955) pointed out that, weight for weight, cancellous bone is as strong as cortical bone. Above the level of the lesser trochanter, therefore, compact and cancellous bone have made a compromise—each accepting a share of the load whilst, at the same time, preserving the tubular nature of long bones elsewhere.

This tubular character of the femoral neck is partly concealed, as Bigelow (1900) suggested, by the developmental addition of the trochanteric traction epiphyses. Removal of the trochanteric system *en bloc* from the anatomical specimen certainly affects but little the radiological pattern of the weight-bearing trabeculae. Furthermore, the mode of attachment of these bulbous trochanters is much in accordance with Bigelow's views. A double-skinned appearance is seen both where the lesser trochanter meets the calcar femorale (Fig. 18) and where the greater trochanter merges with the superior aspect of the neck (Fig. 2).

THE SUB-EPIPHYSIAL ZONE

Microscopic examination of the sub-epiphysial zone shows it to be the meeting place of the medial and lateral elements of the internal weight-bearing system which here approach and fuse with each other for the first time in a series of Gothic arches (Fig. 19). A similar arching arrangement is found at the apex of the intertrochanteric arch, and the circumferential lamellae throughout the entire internal aspect of the diaphysis also terminate in this way (Fig. 20). The above description of the metaphysial lamellae refers only to their appearance in frontal section, and does little to clarify the true nature of their arching disposition. This may be shown by microscopic dissection, however, to represent the cross-section of widely curved bony plates, evenly separated from each other by trabecular tie-beams and merging with their fellows from the opposite cortex in a series of lamellar domes (Triepel 1922). This observation

at once provides a geometric interpretation of these lamellae by which their behaviour may be explained and understood (Fig. 21).

The cancellous patterns of the internal weight-bearing system are therefore formed by wide bony plates or lamellae which, on end section, create the illusion of narrow beam-like structures. The term " trabecula " which has been freely used in describing these cancellous patterns then becomes misleading since this term denotes a small beam. It may justly be

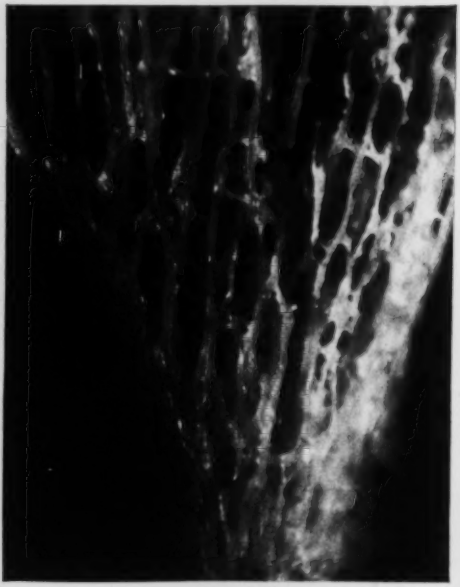


FIG. 16

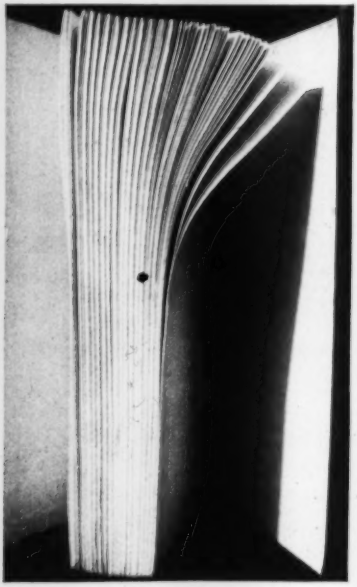


FIG. 17

Figure 16—Microphotograph of the medial lamellae in the internal weight-bearing system to show their mode of origin from the postero-inferior cervical cortex. The expansion of the bone in this region—as at the extremity of all long bones—has been achieved by a splitting-off or lamination of the compact layers of the cortex. Figure 17—The appearance of the lamellae shown in Figure 16 can be compared with that of the ruffled leaves of a book.

applied, however, to the innumerable tie-beams which connect and support the lamellae in the femoral head and neck (Fig. 22). The expression " internal weight-bearing system," which has likewise been used freely, ought not to be held to imply the existence of isolated arrangements of cancellous bone peculiar to the femoral neck, but should be regarded rather as a convenient way to describe the twisted and expanded lamellae in the proximal end of the femur as they are visualised radiologically or on coronal section.

THE EPIPHYSIAL SCAR

During the years of growth the epiphysial plate forms a barrier to the upward extension of the weight-bearing lamellae in the femoral neck. In a young adult femur the site of the epiphysial plate is demarcated by a clearly defined epiphysial scar. It is generally believed that the specialised lamellae of the internal weight-bearing system are then continued upwards through this scar to reach the articular margin of the head, but careful examination shows that this is not so. Neither the medial nor lateral lamellae cross the line of the scar. The medial lamellae are certainly projected into the epiphysial segment of the head, but a well defined breach in continuity may be discerned in each lamella at the level of the scar (Fig. 23), and the lateral group is likewise confined to the sub-epiphysial zone. The epiphysial scar of

early maturity does not persist throughout life but becomes progressively less distinct with advancing years until, in the aged, its remnants are seldom to be seen. The lateral epiphysial arteries run within protective tunnels of laminar bone in the juxta-epiphysial region, and these tunnels may sometimes be mistaken for the epiphysial scar (Fig. 24).

FIG. 18

The junction of the calcar femorale with the inferior cortical buttress of the neck to show double-skinned appearance where the calcar, or " true neck of the femur," has been overlain by the developmental addition of the lesser trochanter.

THE MECHANICAL ASPECTS OF THE FEMORAL NECK

The manner in which the neck of the femur functions as a weight-bearing structure has been the subject of conjecture for many years. Ward (1838) likened the femoral neck to a street-lamp bracket, and Culmann (1866) compared its function to that of a crane. These theories, based upon the appearance of the neck of the femur in frontal section, presume the existence of both compressive and tensile stresses in the internal weight-bearing system. They ignore the fact that, unlike the static forces in wall-bracket or crane, the dynamic strains of weight bearing through the hip joint must form a perpetually changing pattern with every alteration in movement or posture. Furthermore, the femur is not securely anchored to an unyielding base, and its function as a member of the movable linkage supporting and balancing the trunk upon the lower limb is far removed from that of a crane.

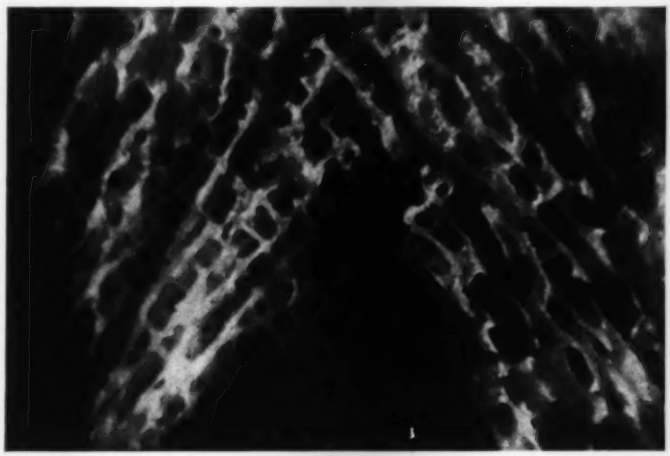


FIG. 19

Microphotograph of the decussation of the medial and lateral lamellae of the internal weight-bearing system in the proximal end of the femur to show the manner of their meeting in a series of Gothic arches in the subepiphysial zone of the head.

The presence of compression forces in the neck of the femur is easy to understand, but the co-existence of tension stresses is not universally accepted. Farkas, Wilson and Hayner (1948) point out that if tensile stresses amounting to two or three hundred pounds were to arise in the upper femoral epiphysis slipping would normally occur since the epiphysial line could hardly withstand such an enormous displacing force.

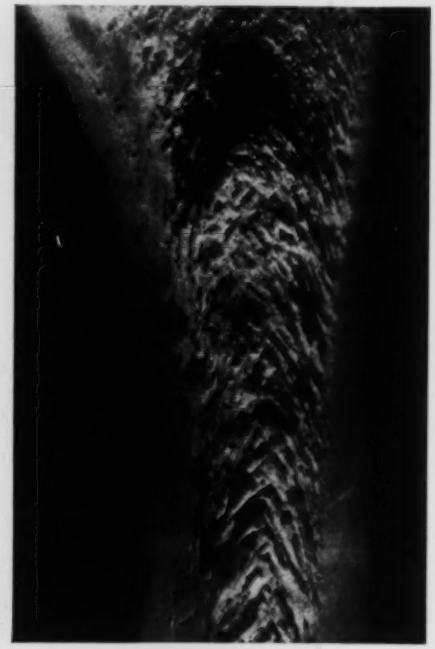


FIG. 20

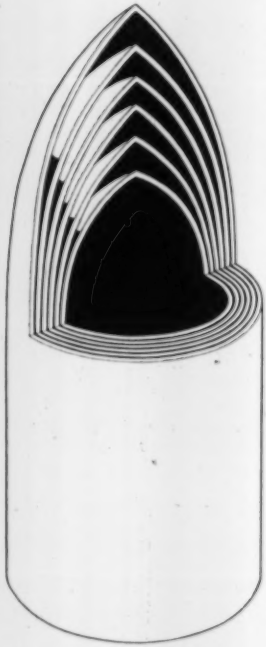


FIG. 21

Figure 20—The arching lamellae on the internal aspect of the femoral diaphysis to show their upward continuation as the expanded lamellae of the metaphysis. Figure 21—Diagrammatic representation of the dome-like termination of the metaphysial lamellae in the proximal end of the femur to show their arching appearance on frontal section.

Some confusion has been caused by the disappearance of the " tensile " lamellae in coxa valga (Fig. 25), and by their increase in coxa vara when they may assume an intensity even exceeding that of the " compression " group (Fig. 26). This variation, however, is not the result of an actual increase or decrease in the number of these lamellae, but depends upon whether they are seen in full-face or profile. In coxa valga they remain in their original position as the circumferential lamellae of the antero-lateral cortex where they are poorly visualised. In coxa vara they expand and rotate to present in profile as clearly defined individual structures. The numerical variation of these lamellae is therefore illusory, and their radiological intensity depends upon the degree of rotation in the femoral neck. Further evidence for this belief is provided by the fact that these so-called tensile lamellae are poorly developed in Neanderthal or Spy men, and are completely absent in primates or quadrupeds (Walkhoff 1904).

The tensile action of the muscles which fix the head of the femur firmly in the acetabulum must be resisted by an equal and opposite compressive force in the femoral neck as a whole. It is difficult, therefore, to accept the presence of two tensile systems in opposition to each other, and if the lateral lamellae of the internal weight-bearing system were indeed to be tensile in nature they would surely buckle as soon as weight bearing was begun. Much thought and argument have been expended by many writers in attempting to clarify this provoking

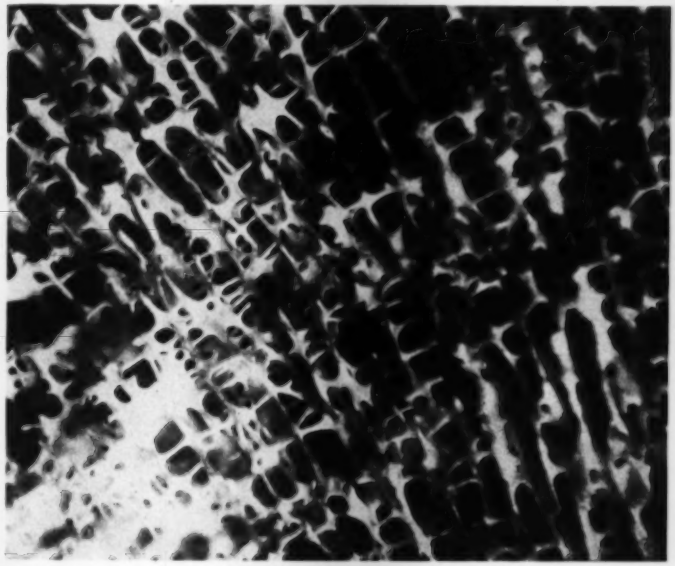


FIG. 22

Microphotograph to show the trabecular tie-beams or " distance pieces " which separate and support the lamellae in the internal weight-bearing system of the femoral neck.

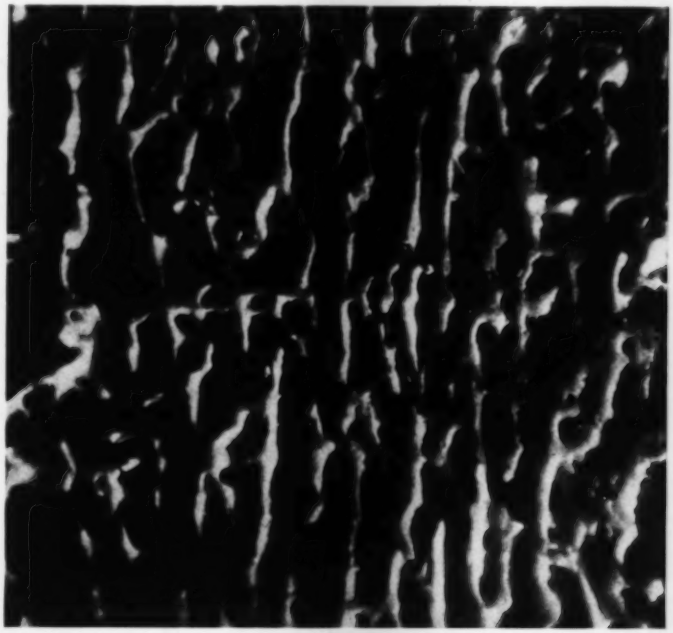


FIG. 23

Microphotograph of the epiphysial scar in the proximal end of the femur. A breach in continuity may be seen between the medial lamellae of the internal weight-bearing system and their fellows in the epiphysial segment of the head.

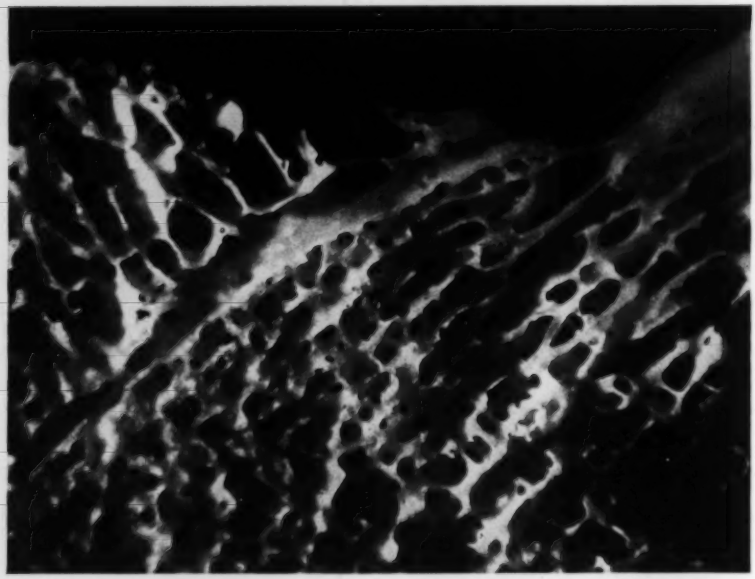


FIG. 24

Microphotograph of laminar tunnel which protects and contains the lateral epiphysial blood vessels at the junction of the epiphysial segment of the femoral head with its underlying subepiphysial zone, and which may be mistaken for the epiphysial scar.

FIG. 25

FIG. 26

Figure 25—Antero-posterior radiograph showing the absence of " tensile " lamellae in coxa valga.
Figure 26—Antero-posterior radiograph showing the relative increase in intensity of the " tensile " lamellae in coxa vara.

problem, and the work of Scott (1957), although in a different context, comes at first sight as an attractive compromise. Scott believes that " the subdivision into tension and pressure stresses is somewhat artificial when applied to an elastic substance such as bone." He suggests that the compression and tension lamellae are both subjected to alternating pressure or tension according to whether the bone is under compression or not, and states that when compression is removed a process of recoil takes place and the compression-tension relationship is reversed. This, of course, is true of steel or any other elastic body subjected to strains and stresses within the limits of its elasticity. The point at issue concerns the initiating force, and the weight of evidence indicates that this is mainly compressive in both medial and lateral patterns of the system under discussion. However this may be, the undistorted head and neck of the femur can certainly continue to function as a weight-bearing unit when decalcification has removed all but the medial system of lamellae. The principal thrust of weight bearing is undoubtedly directed through this almost vertical system which retains its integrity long after the lateral lamellae have been sacrificed to age or to disease. Although it would be presumptuous to oversimplify this intricate mechanical problem by denying the presence of all tensile forces in the neck of the femur, the predominance of compressive forces can safely be assumed.

THE MECHANICS OF THE HIP JOINT

The mechanics of the hip joint are usually depicted diagrammatically in the form of a simple lever, but this fails utterly to indicate the complexity of hip joint function, and in its clinical application has led to many fallacious conclusions. The act of balancing on one leg must involve a most delicate co-ordination not only of the muscles around the hip, but of every major muscle in the body. In particular, the function of the hip joint must be intimately concerned with the function of the knee, ankle and foot. Any interpretation of the action of the muscles which bind pelvis, femur and tibia together should thus be related to their primary purpose of supporting and balancing the trunk upon the movable linkage of the lower limb.

It is well established that in the final stage of knee joint extension the femur rotates medially on the tibia as the knee screws home in full extension. This movement will also be reflected at the hip, and simple observation shows that in weight bearing the hip joint also screws home in medial rotation. Just as the neck of the femur has come to acquire a spiral conformity in the upright position, so also have the soft tissues which surround the hip joint acquired a spiral disposition, and muscular contraction about the hip must imply the application of a rotatory thrust to the femur. An element of torsion will therefore be combined with the compressive forces which are brought to bear upon the femoral neck.

If a femur be freely mounted on a vertical axis with its condyles lying in a horizontal plane and downward pressure be applied to the articular surface of the head, the bone will rotate medially (Fig. 27). This suggests that the shape of the femur has been so perfectly evolved that even in the absence of ligamentous or muscular control its inherent response to weight bearing is to screw home in medial rotation, the rise and fall of its spiral compensating for the tilting axis of the knee.

It is well known that the hip joint is locked by the ilio-femoral, pubo-femoral and ischio-femoral ligaments as they are tightened or wound up by medial rotation of the femur, and stability of the extended hip is in this way achieved with the utmost economy of muscular effort. It is less well known that the head of the femur is not perfectly spherical, and lies in congruity with the acetabulum only in the functional position of weight bearing (Walmsley 1928). The hip joint is generally supposed to resemble the artificial ball and socket joint, but examination of the fresh anatomical specimen, from which all muscles and ligaments have been removed, clearly confirms Walmsley's (1928) observation that this allegedly universal joint actually locks in extension and medial rotation, and can be made to unlock by further movement in these directions only at the expense of subluxation. Aeby (1863) described the femoral head as a rotational ellipsoid, but it may more accurately be visualised as a hemisphere

twisted slightly out of truth articulating with a similarly twisted acetabular runway with which it is congruous only in the position of extension and medial rotation. As Walmsley (1928) stated, the hip is a screw joint.

It thus appears that the femur serves as an independently acting member within its spirally disposed ligamentous and muscular sleeve, and weight bearing at the hip may be regarded as a turn and lock mechanism which depends upon 1) the natural response of the

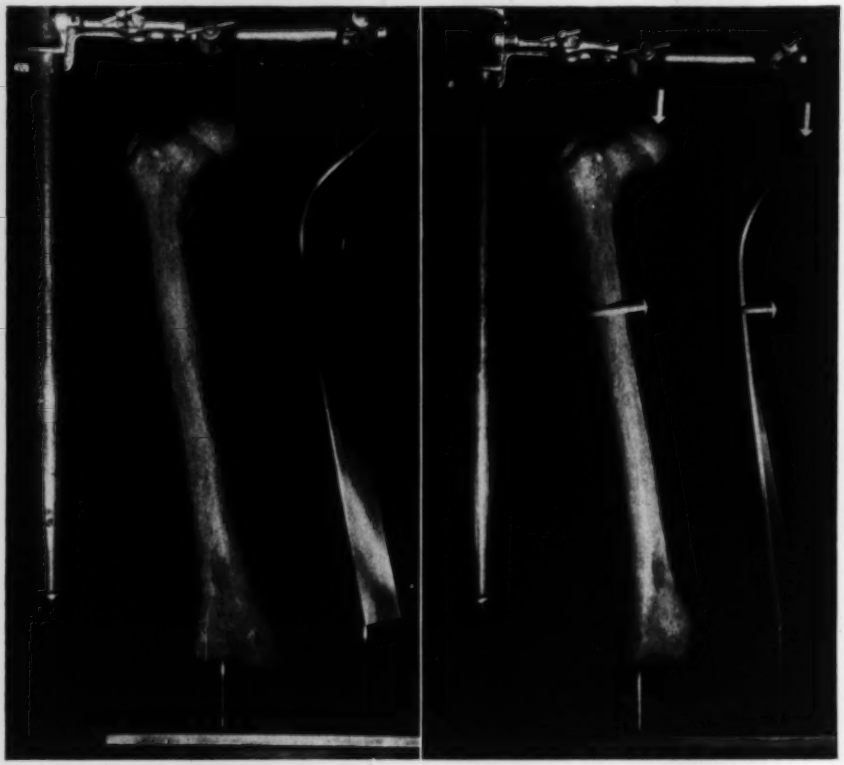


FIG. 27

Experiment to illustrate the response of the femur, in the shape of a vertically mounted spiral, to " screw home " in medial rotation when downward pressure is applied on the medial aspect of its axis.

femur to vertical loading by rotating medially, 2) the locking of medial rotation by the peculiar conformity of the articular surfaces, 3) the restriction of medial rotation by the ligaments about the hip, and 4) the overall control of this rotation by the muscular interplay between pelvis, femur and tibia.

SUMMARY

Many analyses of the geometric arrangement of trabeculae in the proximal end of the femur have accepted and perpetuated the theories of Ward (1838), Culmann (1866) and Meyer (1867), and have contributed to the belief that the structure of the femoral neck embodies mechanical principles which are foreign to bony formations elsewhere. This isolated departure from the normal pattern of skeletal behaviour is considered to be most unlikely, and an attempt has been made to show that the structure of the femoral head and neck departs but little from the normal anatomy of the long bone.

From a developmental point of view, the proximal end of the human femur is believed, in its simplest interpretation, to represent an upward continuation of the original shaft which has undergone rotation and expansion. The cancellous arrangements of the internal weight-bearing system are likewise believed to represent the expanded and rotated lamellae of the neck as they are presented radiologically or on coronal section.

The forces acting upon the proximal end of the femur are considered to be mainly compressive in nature, and both crane and street-lamp bracket theories have therefore been rejected. The spiral conformity of the proximal end of the femur has been related to the spiral disposition of the soft-tissue structures that surround the hip, and in the interpretation of hip joint mechanics the principle of the screw has been preferred to the principle of the lever.

I wish to thank Dr A. A. Miller and his technical staff for their many courtesies in placing the resources of the Pathological Laboratory at Preston Royal Infirmary at my disposal. I am also indebted to Miss M. G. Work, M.S.R., and her team of radiographers who have so willingly undertaken the innumerable radiographic investigations which this study has entailed.

REFERENCES

AEBY, C. (1863): Die Sphäroidgelenke der Extremitätengürtel. *Zeitschrift für Rationelle Medicin*, 3e Reihe, **17**, 204.

BENNINGHOFF, A. (1925): Spaltlinien am Knochen, eine Methode zur Ermittlung der Architektur platter Knochen. *Verhandlungen der Anatomischen Gesellschaft. Anatomischer Anzeiger*. Erganzungsheft zum Band, **60**, 189.

BIGELOW, H. J. (1900): *The Mechanism of Dislocation and Fracture of the Hip*. Boston: Little, Brown and Co.

CULMANN, C. (1866): *Die graphische Statik*. Zurich.

FARKAS, A., WILSON, M. J., and HAYNER, J. C. (1948): An Anatomical Study of the Mechanics, Pathology, and Healing of Fracture of the Femoral Neck. *Journal of Bone and Joint Surgery*, **30–A**, 53.

HARRIS, W. H., and COHEN, J. (1957): The Three-dimensional Anatomy of Haversian Systems. The American Academy of Orthopaedic Surgeons Scientific Sessions, Jan. 26, 1957. *Journal of Bone and Joint Surgery*, **39–A**, 673.

HARTY, M. (1957): The Calcar Femorale and the Femoral Neck. *Journal of Bone and Joint Surgery*, **39–A**, 625.

HIRSCH, C., and BRODETTI, A. (1956): The Weight-bearing Capacity of Structural Elements in Femoral Necks. *Acta Orthopaedica Scandinavica*, **26**, 15.

HUMPHRY, G. M. (1888): On the Angle of the Neck of the Thigh Bone with the Shaft at Various Ages. (Abstract.) *Lancet*, **ii**, 971.

KINGSLEY, P. C., and OLMSTED, K. L. (1948): A Study to Determine the Angle of Anteversion of the Neck of the Femur. *Journal of Bone and Joint Surgery*, **30–A**, 745.

MEYER, G. H. (1867): Die Architectur der Spongiosia. *Archiv für Anatomie, Physiologie, und Wissenschaftliche Medicin*, 615.

SCOTT, J. H. (1957): The Mechanical Basis of Bone Formation. *Journal of Bone and Joint Surgery*, **39–B**, 134.

TOBIN, W. J. (1955): The Internal Architecture of the Femur and its Clinical Significance. *Journal of Bone and Joint Surgery*, **37–A**, 57.

TRIEPEL, H. (1922): *Die Architekturen der menschlichen Knochenspongiosa*. München und Wiesbaden: J. F. Bergmann.

WALKHOFF, O. (1904): *Das Femur des Menschen und der Anthropomorphen in seiner functionellen Gestaltung*. Wiesbaden: C. W. Kreidel.

WALMSLEY, T. (1915): Observations on Certain Structural Details of the Neck of the Femur. *Journal of Anatomy and Physiology*, **49**, 305.

WALMSLEY, T. (1928): The Articular Mechanism of the Diarthroses. *Journal of Bone and Joint Surgery*, **10**, 40.

WARD, F. O. (1838): *Outlines of Human Osteology*, p. 370. London: Henry Renshaw.

EROSION OF THE EPIPHYSIS OF THE RAT TIBIA BY CAPILLARIES

D. A. CAMERON, SYDNEY, NEW SOUTH WALES, AUSTRALIA

From the Department of Pathology, University of Sydney

The lengthening of the shaft of a long bone depends upon the replacement of the zone of provisional calcification in the epiphysial cartilage by bone. This process in turn depends on proliferating capillaries in the metaphysis which invade the epiphysis and allow the penetration of the mesenchymal cells which ultimately produce the bone. The invasion requires that some, at least, of the calcified cartilage be removed, and the cells usually credited with this are osteoclasts. However, these cells comprise only a small fraction of the total cells at the site of this invasion and do not seem to be present in sufficient numbers to account for the rapid replacement of epiphysis by metaphysis which goes on at the rate of about 10μ per hour (calculated from Leblond, Wilkinson, Bélanger and Robichon 1950). A periodic change in the function of the bone cells with osteoblasts aggregating to form osteoclasts and later reappearing as single cells, as suggested by Bloom, Bloom and McLean (1941), Park (1954) and Tonna (1960), might account for the few osteoclasts to be seen at any one time. On the other hand, the rapid absorption of bone under pressure can occur immediately under capillary walls without the presence of osteoclasts (Storey 1955). Evidence that calcified matrix at the epiphysial-metaphysial junction can also be absorbed in this manner is presented in this paper.

MATERIALS AND METHODS

The tissue was obtained from the tibiae of rats weighing 50–70 grammes. Each animal was killed by a blow on the neck and the knee joint was disarticulated. Thin slices were cut in a coronal plane from the upper end of the tibia, care being taken to cover the tissue with fixative immediately it was exposed. Subsequent preparation of the tissue followed the method previously described (Robinson and Cameron 1956). The sections were examined with a Philips EM 100 B electron microscope.

Because of the nature of the tissue it was difficult to avoid distorting it during both the initial slicing and the cutting of sections. In the first place the slices were composed of soft and calcified tissue and the very act of cutting the fresh tissue tended to tear the two components apart; secondly, the tissue was not decalcified before sectioning and knife marks and fragmentation sometimes occurred. The sections also tended to fold along lines separating zones of varying density, particularly where there were projections of calcified tissue into cellular areas.

OBSERVATIONS

Figure 1 is a photomicrograph of the junction of the epiphysis and metaphysis, and all the electron micrographs represent fields in this region. A section of one of the thin-walled capillaries which penetrate the metaphysial surface of the epiphysis is shown in Figure 2. It is lined by a single layer of endothelium (A) with various supporting cells in association with it. The capillary is very close to the epiphysis, as is demonstrated by the thin layer of newly formed bone (B), which covers the core of calcified cartilage (C). The apparently isolated areas of calcified tissue (Figs. 3 to 5) are the remains of one of the lateral bars which originally separated two cartilage cells. They can be shown to be attached to the main framework of the primary spongiosa at a short distance from the plane of section represented by Figure 2, and both are projections from a fenestrated calcified " cylinder " surrounding the capillary.

The surface of each of these projections is in close relationship to the overlying endothelial cells (Figs. 6 to 8) and is composed of a loose aggregate of apatite crystals and fragments of organic material. At a short distance from the capillary wall the calcified tissue is compact

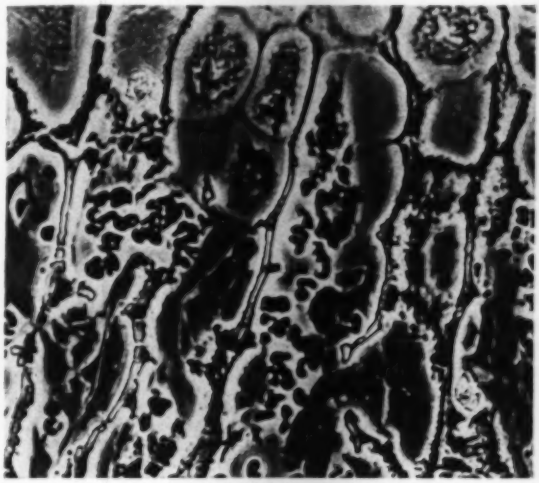


FIG. 1

The junction of the epiphysis and metaphysis. Phase contrast photomicrograph to show the region illustrated by the electron micrographs in Figures 2 to 10. (×400.)

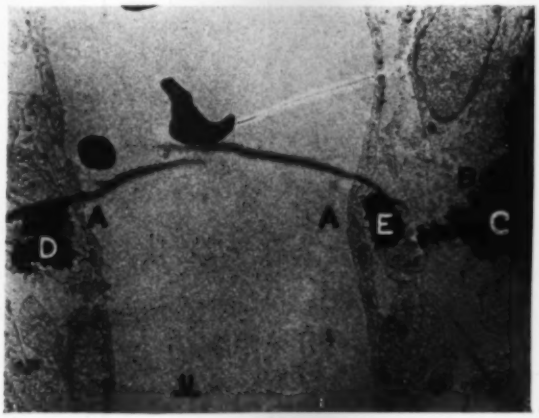


FIG. 2

Capillary penetrating the epiphysis. A, endothelial cells. B, thin layer of bone covering core of calcified cartilage C. The two isolated pieces of calcified tissue, D, E, are the remains of a continuous bar which originally separated two cells in a column of chondrocytes in the epiphysis. They are both part of the primary spongiosa although this is not apparent in this figure. (×3,500.)

and the surface (A, Fig. 3, where new matrix is being formed), while irregular, is quite different in appearance from that next to the endothelial cell.

Part of an osteoclast is shown in Figure 9 and its relationship to matrix which is being absorbed is shown in Figure 10. The matrix nearest the cell is fragmented and composed of

apatite crystals and organic material. (The cell lies in a saddle-shaped lacuna and the " isthmus " (A, Fig. 9) between the denser areas is in a plane almost tangential to the interface between matrix and cell.)

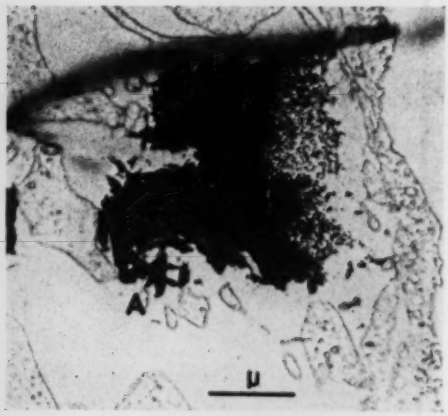


FIG. 3

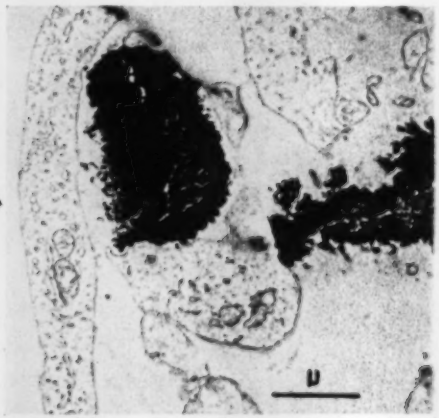


FIG. 4

Figure 3—Enlargement from Figure 2 to show the intimate relationship between the capillary endothelium and the calcified tissue. A, surface where bone is being laid down. (×13,000.) Figure 4—Enlargement from Figure 2, opposite side of capillary to that in Figure 3. (×13,000.)

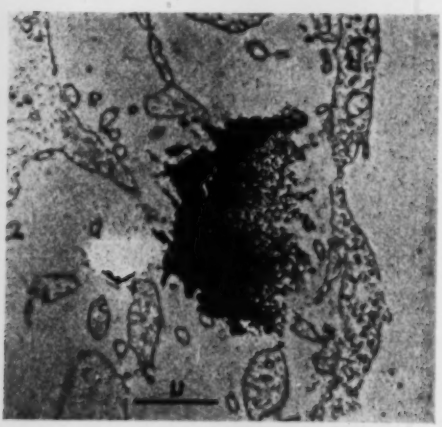


FIG. 5

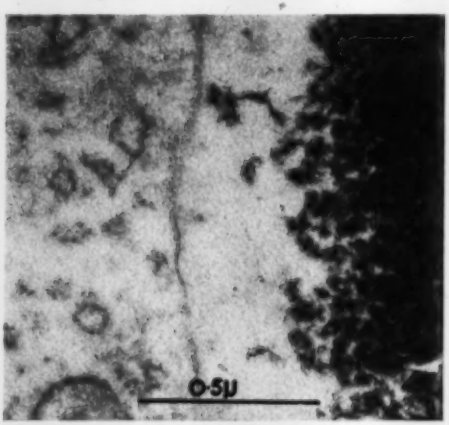


FIG. 6

Figure 5—Field from section in series with that represented in Figure 3. (×13,000.) Figure 6—Enlargement from Figure 4. (×56,000.)

DISCUSSION

The junction between the epiphysial cartilage and the shaft of the tibia is composed of a honeycomb of calcified cartilage and bone (Fig. 1), the spaces of which are occupied by capillary buds and supporting cells growing from the metaphysis. Space is made for the advancing vascular tissue by erosion of some of the calcified tissue and this is usually stated to be carried out by osteoclasts.

The surface of calcified cartilage or bone which is being attacked by an osteoclast has the appearance shown in Figure 10. The matrix seems to be disintegrating and the apatite crystals (A) lie among fragments of organic material (B). This picture is quite different from that

found where matrix is becoming mineralised (A, Fig. 3). However, it is not confined to osteoclastic absorption but can be found where the matrix is in direct contact with the endothelium of the capillaries (Figs. 6 to 8).

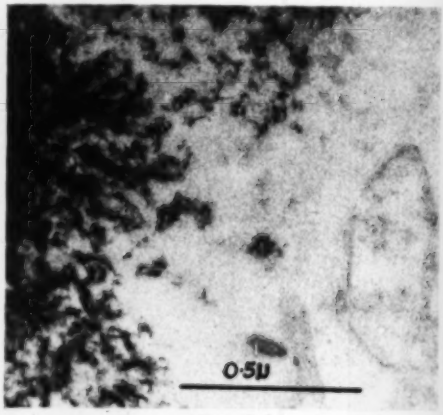


FIG. 7

Figure 7—Enlargement from Figure 3. (×56,000.)

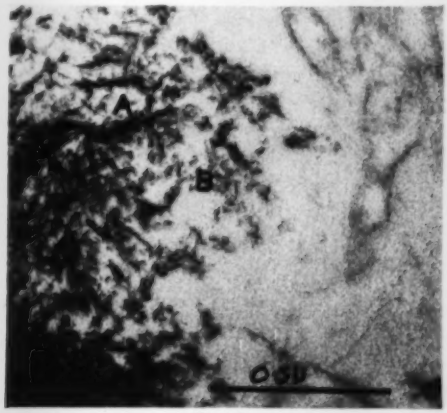


FIG. 8

Figure 8—Enlargement from Figure 5. The apatite crystals, A, and organic fragments, B, can be seen most clearly in this figure. (×56,000.)

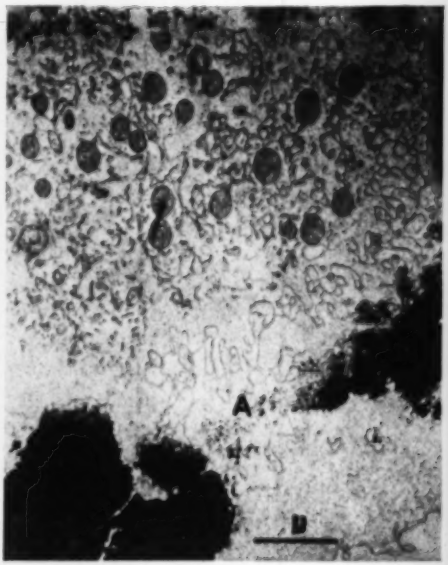


FIG. 9

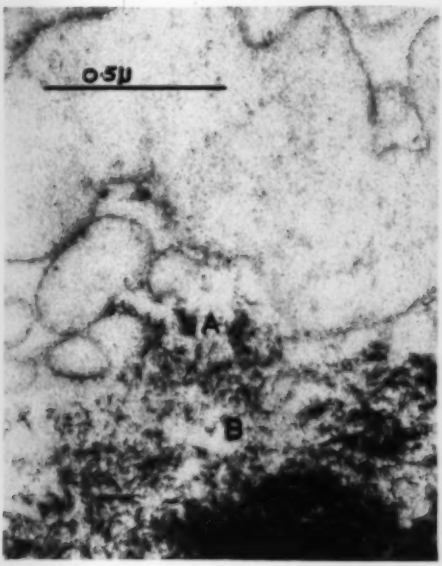


FIG. 10

Figure 9—Part of an osteoclast lying on bone which it has eroded deeply at the area marked A, forming a saddle between the dense bone shown at each side of the figure. (×13,000.) Figure 10—Enlargement from Figure 9 to show the disintegrating calcified matrix under the convoluted cytoplasm of the osteoclast. A, apatite crystals. B, fragments of organic material. (×56,000.)

This appearance in relation to endothelial cells could be accounted for in at least two ways. It is well known that osteoclasts migrate (Hancox 1956, Gaillard 1959), and one could have been spread thinly over the matrix at a short distance from the plane of section represented

by Figure 2. There has been no suggestion of this in the material examined, although, owing to the difficulty of cutting and mounting large series of sections of undecalcified bone, it has not yet been possible to observe the whole circumference of a capillary. The removal of mineral on both sides of the capillary simultaneously by osteoclasts which have since moved away seems unlikely. Further, if the appearance of Figures 6 to 8 is to be attributed to an osteoclast, one might also expect to see the remnants of disintegrating matrix underneath osteoblasts which have taken the place of migrating osteoclasts or which have been derived from osteoclasts, but this has not been the case up to the present time. This means that fragmented matrix is only found close to the cells responsible for its disruption and leads to the consideration of another possibility. Endothelial cells or the mere presence of a capillary could bring about the disintegration of the matrix. Storey (1955) described the changes in bone subjected to the pressure of tooth movement and noted that the bone was absorbed in the absence of osteoclasts. This observation, as well as the arguments advanced above, justifies the conclusion that osteoclasts need not always be required for the absorption of calcified cartilage and bone.

An explanation of the mechanism involved is not easy to find. Figures 6 to 8 show that there is disintegration of the organic matrix while many crystals remain intact. There may have been solution of the apatite with subsequent recrystallisation, but it seems that, free from their normal relationship to collagen fibrils, the new crystals would not be so similar to those in the unaffected matrix. Possibly there has been dissolution of only some of the crystals, perhaps sufficient to allow their separation from the collagen. This partial decalcification could leave the organic matrix open to attack and might be brought about by an accumulation of citrate in the advancing capillary buds. The blood within the blind ends of these buds would not be circulating during the earliest stages of capillary erosion, and deficiency in oxygen might cause an increase in citrate concentration. The other step in the process, removal of matrix, could be accomplished by proleolytic enzymes but the source of these is not yet established.

SUMMARY

Calcified matrix that is being absorbed has a characteristic appearance. At the junction of the epiphysis and metaphysis in the rat tibia this appearance can be seen near capillary endothelium as well as under osteoclasts. It is concluded that absorption can take place under the walls of capillaries without the presence of osteoclasts.

This work was supported by grants from the National Health and Medical Research Council, the New South Wales State Cancer Council, the Post-Graduate Medical Foundation and the Cancer Research Committee, University of Sydney. My thanks are due to Professor B. T. Mayes for the use of the electron microscope in the Queen Elizabeth II Research Institute for Mothers and Infants, University of Sydney.

REFERENCES

BLOOM, W., BLOOM, M. A., and MCLEAN, F. C. (1941): Calcification and Ossification. Medullary Bone Changes in the Reproductive Cycle of Female Pigeons. *Anatomical Record*, **81**, 443.

GAILLARD, P. J. (1959): Parathyroid Gland and Bone in Vitro, VI. *Developmental Biology*, **1**, 152.

HANCOX, N. (1956): The Osteoclast. In *The Biochemistry and Physiology of Bone*. Edited by G. H. Bourne. New York: Academic Press Inc.

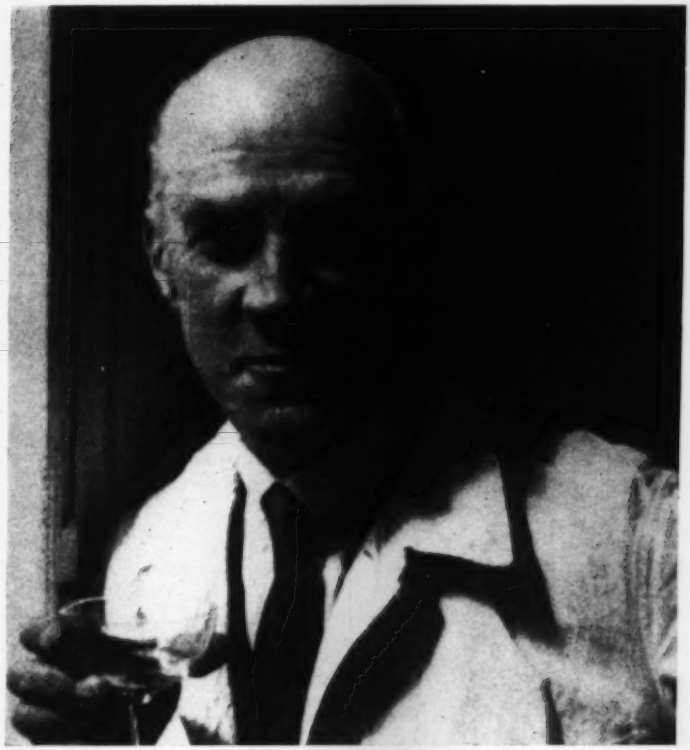
LEBLOND, C. P., WILKINSON, G. W., BÉLANGER, L. F., and ROBICHON, J. (1950): Radio-autographic Visualization of Bone Formation in the Rat. *American Journal of Anatomy*, **86**, 289.

PARK, E. A. (1954): Bone Growth in Health and Disease. *Archives of Disease in Childhood*, **29**, 269.

ROBINSON, R. A., and CAMERON, D. A. (1956): Electron Microscopy of Cartilage and Bone Matrix at the Distal Epiphyseal Line of the Femur in the Newborn Infant. *Journal of Biophysical and Biochemical Cytology*, **2**, Supplement 253.

STOREY, E. (1955): Bone Changes Associated with Tooth Movement. A Histological Study of the Effect of Force for Varying Durations in the Rabbit, Guinea Pig and Rat. *Australian Journal of Dentistry*, **59**, 209.

TONNA, E. A. (1960): Periosteal Osteoclasts, Skeletal Development and Ageing. *Nature*, **185**, 405.



HAROLD ARTHUR THOMAS FAIRBANK

Kt., D.S.O., O.B.E., M.S.Lond., F.R.C.S.Eng.,
Hon.M.Ch.Orth.L'pool., Hon.F.R.S.M.Lond.

1876–1961

Sir Thomas Fairbank will be remembered as a leader of surgery in Great Britain who shared with Sir Robert Jones, his senior colleague and friend, the pioneering endeavours of the nineteen-twenties by which orthopaedic surgery became recognised and established as one of the major parts of general surgery and medicine. He will be remembered also as Tom, or more affectionately as Uncle Tom, who again shared with Robert Jones the sterling qualities of integrity, sincerity and modesty, with courteous thoughtfulness for juniors such that they became inspired as disciples. Thus each of these leaders achieved the immortality of which we can be certain—the stimulating influence of one life upon the lives of others so that their own contributions to the welfare and happiness of mankind are multiplied and perpetuated.

Thomas Fairbank was a founder member of the British Orthopaedic Association in February 1918, and when he died in February of this year he shared the surviving influence of our founders with only two others, Rocyn Jones and Harry Platt. He was vice-president to Robert Jones throughout the five years of that memorable leadership; then president himself in 1926–27; and thereafter Emeritus Fellow, the first so to be honoured. In 1929 he was a founder member of the International Society of Orthopaedic and Traumatic Surgery,

and later vice-president in Bologna and Rome. He was vice-president of the orthopaedic section of the British Medical Association at its centenary meeting in 1932; president of the orthopaedic section, and of the paediatric section of the Royal Society of Medicine, in later years gaining the rare distinction of honorary fellowship. He was Robert Jones Lecturer in the Royal College of Surgeons of England in 1938, but even more was he inspired by the Lady Jones Lectureship in Liverpool in 1929.

It is through the allegiance of Fairbank to Liverpool and to Robert Jones that I first met him. Then I did not know that he was one of a family of five whose father, a medical practitioner in Windsor, had died when he was young; that he was an Epsom boy who had qualified in the Charing Cross Hospital Medical School; had foregone his earlier destiny to dental surgery; had been a civil surgeon in the Boer War, meeting Lord Roberts, Lord Kitchener, Rudyard Kipling and Conan Doyle; in the first world war had driven mules and ambulances in Salonika —or was it Greece or Macedonia—I did not know. I knew only that he was the great leader of orthopaedic surgery in London, consultant to King's College Hospital where he had established the first fracture clinic in London, and to the Great Ormond Street Hospital for Children and the Lord Mayor Treloar Orthopaedic Hospital at Alton. What mattered to me was that he was the first external examiner for the Liverpool degree of M.Ch.Orth. and that with Robert Jones he was examining me as one of the first three candidates. Could I ever forget his grumpy kindness when having asked me to do a Stöffels bilateral obturator neurectomy by the abdominal approach he assisted me with a retractor in one hand and a lighted match within the stiff cadaveric abdominal walls with the other?

In later years when I assisted him at Great Ormond Street, and his endeavour was concentrated on trying to solve the problems of congenital dislocation of the hip, could I ever forget the kind growl of his voice that was so tender to children that they knew at once that he could be trusted? In later years when he had the heavy responsibility of directing the orthopaedic organisation of the Emergency Medical Services of Great Britain in the second world war, and I had to compete gently for another orthopaedic service in the Royal Air Force, could there ever have been warmer or more courteous understanding? In days of peace did he not hold the greatest second-opinion private practice ever known by reason not only of his wisdom but his integrity? And as if we were not already bound as disciples, could he have given more stimulus to those of us who were young in creating the British Volume of the *Journal of Bone and Joint Surgery* than his series of contributions on disorders of bone growth, which had been a life-study and a life-collection, over which he chuckled so happily for so many years after his deafness commanded retirement from active practice, and was then published as a classic with the modest title: *Atlas of General Affections of the Skeleton.*

One other important contribution he made to surgery has for the moment been dimmed by reason of the development of chemotherapeutic antibiotic drugs. But most surely it will arise again and, just as he learned it from Arbuthnot Lane, we will again learn it from him because sooner or later we will know that the basic protection of surgical cutting can never be antibiosis or antisepsis but only asepsis. His operative technique was superb, and only the angry young men of welfare states will say that non-touch technique as practised by this grand old man is difficult or impossible or unnecessary.

So brief a tribute as this to a great surgeon, kind counsellor and good friend would be unhappy if tribute had not been paid during life, but many of Thomas Fairbank's colleagues and friends shared the honour of a *Festschrift* on the occasion of his eightieth birthday in the publication of the British Volume of the *Journal of Bone and Joint Surgery* in February 1956. All of them, and all of us, bow in homage and treasure our memories of the man whose sincere and happy life is shown in the snapshot chosen for printing today by his son John, now in the orthopaedic service of the Cambridge Hospitals, and Lady Fairbank whose devotion to life was centred in the work of her husband.

R. W.-J.

IN MEMORIAM

JOHN WILLIAM VAN REES HOETS
1885–1961

John Hoets died in his seventy-sixth year on March 17, 1961, in the Scottish Hospital, Sydney —the hospital he loved so well and in which he had done so much of his work.

Few men can have been so loved by both his colleagues and his patients as John. To his patients he gave a lifetime of selfless service and devotion, and of him it can be truly said that the patient always came first. He never postponed setting a fracture to the following day, no matter what the hour and the personal inconvenience of making the necessary arrangements, including x-ray control. Rare indeed would be the time he did not visit his patient in hospital on the evening before operation and the evening after. I know well what a physical effort this visit often was at the end of a long day but it was never neglected. Small wonder then that, after his many years in busy practice the patients, colleagues and friends who mourn his passing are legion, and many have a feeling of acute personal loss. His wonderful gift of unhurried understanding gave his patients the comfortable feeling that in him they had a counsellor and friend as well as a very gifted surgeon.

He was born in Boorowa, in the Southern District of New South Wales, the son of a country practitioner. His schooling was in Goulburn, and later at the King's School for two years before University. He had a fine sporting record. He represented the school in rugby union football and in cricket, and was in the Combined Great Public Schools football team. He was appointed captain of the school. Later he represented his university at rugby and was a member of the team of 1905, probably one of the best that the university ever produced. He gained representation in the Combined Universities' team which toured New Zealand in that year and later gained a place in the New South Wales team against Queensland.

After graduation he entered general practice, and for some years was in the Glebe, first in partnership with the late S. A. Smith, later to become a distinguished physician, and then with the late Theo. Potts, whose name will always be associated with the brilliant anatomical dissections in the Museum of the Anatomy School. During this period he became associated with John Hunter and Normal Royle in their experimental work on the sympathetic nervous system, and for some years he gave Royle's anaesthetics in both his experimental and clinical surgery. About this time he was for a brief period Honorary Gynaecologist at the South Sydney Hospital. However, about 1920 he moved from the Glebe to Bellevue Hill where he lived to within a few weeks of his death, and it was then that he interested himself in orthopaedic surgery which was to be his true life's work. Within a few years he had given up general practice and began his busy life as a consultant orthopaedic surgeon in Macquarie Street.

He was a Foundation Member of the Australian Orthopaedic Association and a Foundation Fellow of the Royal Australasian College of Surgeons. He was for some years an Examiner in Orthopaedic Surgery for the College, and in the years 1947–49 he was President of the Australian Orthopaedic Association. This was a fitting climax to his career because there can have been few men held in higher esteem by his colleagues.

His hospital appointments were many, and he was for many years the senior orthopaedic surgeon to Lewisham and Sydney Hospitals. On his retirement from the active staff at the latter the orthopaedic outpatients' department was named after him. During and for a time after the second world war he also undertook honorary appointments at Western Suburbs Hospital and Prince Henry Hospital. Despite an affliction of both feet which plagued him for the greater part of his life and rendered him unfit for overseas military service during the war, he yet found time to do consultant orthopaedic work at the Concord Military Hospital. With also the numerous private hospitals at which he operated, and the enormous size of his private practice in those years, the work he performed must have been simply stupendous, and, as he often told me, it allowed of no holidays or week-end relaxation.

In addition, during these years and before and after the war for a time this remarkable man found the time to take active interest in such bodies as the Australian Physiotherapy Association, the Far West Children's Health Scheme, and the Society for the Physically Handicapped. Even so, up to the age of seventy he played a respectable game of golf and was a tough opponent.

His wisdom and technical skill as an orthopaedic surgeon were superlative, but it will always be as a man rather than a surgeon that John will be remembered by his friends and colleagues. A most charming and kindly personality in which consideration for others was paramount; a wonderful sense of humour and a lover of good stories; a deep and abiding interest in the younger members of the profession who subsequently had the benefit of his unobtrusive help and advice; these are the things with which his memory will always be associated.

To his widow, and son and daughter, goes the heartfelt sympathy of all who knew and loved him.

W. S.

PROCEEDINGS AND REPORTS OF UNIVERSITIES COLLEGES, COUNCILS AND ASSOCIATIONS

GREAT BRITAIN

THE BRITISH EDITORIAL BOARD, JOURNAL OF BONE AND JOINT SURGERY

RETIREMENT OF THE CHAIRMAN, SIR WALTER MERCER

Sir Walter Mercer, Chairman of the British Editorial Board of the *Journal of Bone and Joint Surgery*, and of the British Editorial Society of Bone and Joint Surgery since 1954, has retired from office and from the Board with effect from June 10, 1961. At a farewell ceremony on June 9 the British Editor, Sir Reginald Watson-Jones, on behalf of present members of the British Editorial Board, presented to Sir Walter a Georgian silver inkstand in recognition of their very high esteem and of his long and valuable service to the Journal. His colleagues know how very great was his contribution and how very much his wisdom and good humour will be missed.

Sir Reginald Watson-Jones (*left*) presenting a silver inkstand to Sir Walter Mercer, the retiring Chairman. Looking on is Mr H. Jackson Burrows, who succeeds Sir Walter as Chairman.

APPOINTMENT OF MR H. JACKSON BURROWS AS CHAIRMAN

At a meeting of the British Editorial Board and of the British Editorial Society of Bone and Joint Surgery Mr H. Jackson Burrows, Deputy Editor since the foundation of the British Journal in 1948, was unanimously elected Chairman in succession to Sir Walter Mercer.

BRITISH ORTHOPAEDIC ASSOCIATION

SPRING MEETING

The spring meeting of the British Orthopaedic Association was held in Manchester from April 13 to 15, 1961. Mr H. J. Seddon, the President, was in the chair. The President welcomed a number of members and guests from abroad, including Dr Carl Badgely (Ann Arbor), Dr H. Wouters (Utrecht), Dr Marshall Urist (Los Angeles), Professor C. E. L. Allen (Cape Town), and the five Travelling Fellows from North America—Dr E. Burke Evans (Galveston), Dr J. T. H. Johnson (Baltimore), Dr William R. MacAusland (Boston), Dr William Snell (Portland), and Dr John W. Hazlett (Kingston, Ontario).

Mobility and instability in the cervical spine—*Dr J. Ball* (Manchester) said that in rheumatoid arthritis instability occurred either at the atlanto-axial joint, which was the commoner, or in the cervical spine below. At the atlanto-axial level subluxation resulted from stretching of the transverse ligament which became eroded at its attachment at either end. The slip took place slowly and its extent depended on the elasticity of the posterior ligaments. It might be halted by spontaneous ankylosis. At a lower level subluxation resulted from erosion of the disc-bone junction by pannus from the neuro-central joints. The degree of subluxation depended more on the posterior ligaments than on the annulus of the disc. This had been shown experimentally. Neurological changes associated with subluxation were uncommon, and when they did occur they were not severe. *Dr J. Sharp* (Manchester) said that subluxation was more common in these patients than was generally supposed. This constituted a danger in general anaesthesia. Population studies showed that 18 per cent of those over sixty-five years of age had some degree of subluxation in the neck. *Professor J. H. Kellgren* (Manchester) asked if there was any information about the extensibility of the ligaments. Dr Ball, in reply, said that he had been unable to find any microscopic change in the ligaments themselves.

Paraplegia in extension injuries of the spine—*Mr C. H. Cullen* (Manchester) reported the necropsy findings in five patients who had died after hyperextension injuries of the spine. In all, the spine was either aged or in some way abnormal. Examination of the patients suggested that the extension force was always combined with rotation, and in all patients the anterior common ligament was ruptured. The posterior common ligament was stripped up for two vertebrae above and below and it was compression of the cord between this and the laminae which caused the damage. He had been able to demonstrate this experimentally and by myelographs. Pressure was relieved immediately by reduction. The disc itself was not disrupted but was torn off the bone. Healing was by fibrosis and not by regeneration. *Mr R. Roaf* (Oswestry) doubted if the anterior common ligament was always ruptured. He thought the posterior ligament was sometimes ruptured and that there might be a posterior shift which caused the paraplegia. *Professor Roland Barnes* (Glasgow) said that he did not now believe that the anterior common ligament must always be ruptured to produce paraplegia. In ankylosing spondylitis Queckenstedt's test was positive when the neck was extended. The margin of safety in spondylitic spines was very small, and even trivial injuries could cause cord damage. Mr Cullen, in reply, said that there were many patients with cord damage who survived, but in the five he had examined at necropsy the anterior common ligament was ruptured. He emphasised that the ligament could join so well that the damage could be seen only with a microscope.

The halo traction apparatus: a method of external splinting of the cervical spine after injury—*Mr Harral Thompson* (Manchester) said that external fixation of the neck by the usual " minerva " plaster was poor, adjustment was difficult and radiography presented a problem. The Perry-Nickel " halo " splint overcame many of these difficulties. He described the application of the splint, which was fixed to a previously applied plaster jacket with well padded shoulder straps. The splint was fixed to the skull by four special sharp-pointed screws which were introduced through the skin under local anaesthesia and perforated the outer table. The position of the splint (and head) could be adjusted by screws. The patient could get up the next day. Adjustment of the position and radiography were simple and the fixation for operation was excellent. The screws could easily be replaced if infection or slipping occurred. *Mr J. Rowland Hughes* (Oswestry) said that he had found that the jacket tended to slide up rather than down and that he had found that the thick shoulder straps made radiography of the lower cervical spine impossible. *Mr F. C. Durbin* (Exeter) asked if it was successful in the treatment of lower cervical lesions. The reply was that immobilisation was satisfactory in such cases but that radiography was difficult. *Mr J. Chalmers* (Edinburgh) said that they had used the splint but without the shoulder straps. Discarding the straps did not seem to interfere with its efficiency. *Mr I. S. Smillie* (Dundee) said that the disadvantage of the splint was that it fixed the skull but not the trunk. *Mr J. N. Wilson* (London) said that open reduction was difficult with the splint.

Cellular immunity and the bone graft—*Mr R. G. Burwell* (Leeds) said that it had been shown that skin transferred as a homograft was rejected by an actively acquired immunity developing in the regional lymph nodes. The instruments of this rejection were not serum antibodies but antibodies bound to cells in the lymphoid series. In thirty-four rabbits which received the primary or secondary bone homografts no serum antibodies developed. Experiments in seventy rabbits showed that a characteristic cellular response was found in the regional lymph nodes draining homografts but not autografts, and the lymph nodes were increased in weight. These cells gave rise by mitosis to antibody-carrying small lymphoid cells which were carried by the blood stream to the homograft and caused its rejection. This response reached its maximum at the fourteenth day. Experiment had shown that the antigenic component was not the bone trabeculae but the nucleated cells of the bone marrow. Treatment of the bone chemically, thermally or by irradiation removed its antigenicity with the exception of bone frozen to −79 degrees Centigrade. *Mr J. Chalmers* (Edinburgh) thought that a

serum antigen did develop after a homograft, even if it had been frozen, but it developed late and slowly. *Dr J. Ball* (Manchester) asked what happened to the implanted homograft. *Dr Marshall Urist* (Los Angeles) said that cortical bone would produce antigen changes, due to the Haversian canals. Mr Burwell, replying, said that if serum antigens were present they were very difficult to find. He said there was an intense cellular reaction around the graft.

A qualitative method of estimating changes of blood-flow in bone—*Dr A. McPherson* and *Mr N. E. Shaw* (London) described a method of estimating the blood-flow through bone by means of a thermocouple inserted into the bone marrow. This was compared with the changes found from another thermocouple inserted into a muscle and with the marrow pressure. They found that the rise and fall of blood pressure, marrow pressure and the thermocouple readings in bone and muscle were related but not quantitatively. *Mr J. N. Wilson* (London) asked if the size of the vessels near the thermocouple might give misleading readings. Mr Shaw agreed that this was so. They had excluded the effect of soft tissue by means of a tourniquet and had shown by injections of Pantopaque that there was still a return through the bone marrow.

Arthroplasty of the hip by the low-friction technique—*Mr John Charnley* (Manchester) had devised a new form of hip arthroplasty based on studies of joint lubrication in animals. The friction between bone and substances commonly used in arthroplasty was high. But a low coefficient of friction, almost approximating that of a normal joint, was obtained by using polytetrafluorethylene (" Teflon " or " Fluon "). This plastic was inert and was suitable for implantation. The method consisted in the implantation of a thick-walled Fluon " cup " into the acetabulum which had been reamed to size. The " cup " was held in position by means of serrations on its outer side and a projection which extended through the floor of the acetabulum. A metal prosthesis with a small head was cemented into the femur. The operation had been carried out in its present form in fifty-one patients and it had been found that even in severely disabled patients with rheumatoid arthritis there had been relief of pain. An excellent range of movement was obtained at once and rehabilitation was easy. Very little new bone formation around the acetabulum was encountered, possibly due to the absence of any friction between prosthesis and bone. An important part of the operation was that the detached greater trochanter was reattached securely lower down the shaft by wires. *Mr G. K. McKee* (Norwich) said that he had been doing a similar operation but using an all-metal joint since 1950. Fifty-six per cent had been satisfactory. The failures were due to the apparatus coming loose, and the use of cement was a great advance. He had now reverted to using a normal-sized head and cup. He had once had to remove a cemented prosthesis at six months and had found it to be very firm. *Mr W. D. Coltart* (London) asked if there was any trouble with the acetabulum through foreign body reaction. *Dr J. T. Scales* (London) asked why Mr Charnley used a steel prosthesis. He wondered whether there would be any wandering of the acetabulum through reaction. Mr Charnley, in reply, said that chrome cobalt would be better than steel and he would use it in future. Engineers were quite happy about the durability of Fluon, which did not cause any soft-tissue reaction. He used the smallest head possible in order to reduce friction to a minimum.

Osteoarthritis as seen in random samples of the population—*Professor J. H. Kellgren* and *Dr J. S. Lawrence* (Manchester) described the findings in random samples taken from urban and rural populations in a comprehensive study of arthritis. A distinct pattern of osteoarthritis was noted in men and in women. In women it usually affected several joints and was associated with Heberden's nodes and a raised cholesterol level. This type of arthritis presented a typical appearance in which, whereas osteophyte formation was pronounced, the joint space was little affected and symptoms were usually minimal. This suggested that in women osteoarthritis was often a generalised disease related to constitutional factors and might be preventable by dietetic methods. In men the site and severity of degenerative changes were closely related to occupational stresses and other mechanical factors. Multiple joints were less frequently involved. A total of 1,500 men and women over the age of fifty-five years had been investigated for possible osteoarthritis of the hips. These came from the mining town of Leigh and from the agricultural area of Wensleydale and from South Wales. Radiography of the pelvis was carried out in 830, and osteoarthritic changes in the hips varying from slight to severe were found in 13·5 per cent. In more than 50 per cent the condition was associated with a more generalised arthritis. *Mr K. I. Nissen* (London) said the survey suggested that 100,000 people in this country suffered from crippling osteoarthritis of the hip. He showed a film which purported to show that osteotomy without any displacement could arrest early primary osteoarthritis. *Professor Bryan McFarland* (Liverpool) asked why the ankle and wrist were spared. Professor Kellgren, replying, said that generalised osteoarthritis could come from living habits, injuries or metabolic changes. He emphasised that in many osteoarthritic hips the pain was phasic. He did not know why the ankle and wrist were spared in primary osteoarthritis.

Bone growth following fusion operations—*Dr J. T. H. Johnson* (Baltimore) said that just when we had come to accept the fact that bones grew in length from their metaphyses the whole problem was again put in doubt by the question whether bone grafts of the spine increased in length, and if so, how? Although many of the statements supporting the view that interstitial growth in length took place could be discounted on the grounds that artefacts resulting from magnification or the presence of pseudarthroses, etc., had not been taken sufficiently into account, there were a few cases remaining among the 400 he had examined in which it seemed that elongation of the graft had actually occurred. He had carried out experiments to determine how this happened. Fibular grafts were placed across the growing tibial epiphysial line. He was able to show that in those grafts which became soundly incorporated and which were not absorbed microscopically, obvious pseudarthroses developed which allowed stretching and then underwent spontaneous healing as the host bone increased in length. The same process could occur in spinal fusion and would make it very difficult to obtain a really sound graft in a child, though perhaps a very massive graft might overcome this. *Mr T. J. Fairbank* (Cambridge) asked how the elongation of the bowed tibia of Paget's disease took place. Dr Johnson replied that it could occur only by multiple minute fractures.

Osteoporosis—*Dr Marshall R. Urist* (Los Angeles) reported his findings in eighty-seven patients in whom definite evidence of osteoporosis was found. One function of bone was storage, and if the output from the bone exceeded input osteoporosis resulted. Radiography did not disclose any change until there had been a loss of 30 per cent of bone mass. Two main types of osteoporosis could be differentiated: 1) the hormonal type, exemplified by Cushing's syndrome, hyperparathyroidism or acromegaly, which was found in relatively young people; and 2) non-hormonal or low-hormonal influenced osteoporosis, generally found in individuals of fifty years of age or more. The cause of this type of osteoporosis was unknown. It was not clear if it was a specific disease or the physiological process of ageing bone. Biopsy of bone (tibia) showed that the cortex was thinned, but the fact that tetracycline fluorescence was present showed that there was, in fact, increased activity of new bone formation and of absorption. He considered that osteoporosis was a physiological disorder associated with an increase of activity but with slow tissue loss, and that patients were using up their own calcium instead of absorbing it from the bowel. *Dr B. E. C. Nordin* (Glasgow) asked why the results of isotope and tetracycline deposition were so very different. He questioned the value of dietetic balances unless a diet resembling the patient's home diet was used. He thought it wrong to draw deductions from biopsy of one bone only. Sometimes the long bones alone would be affected and not the spine, or *vice versa*. *Professor J. H. Kellgren* (Manchester) asked to what extent increased activity in bone was due to increased demand. *Mr H. J. Seddon* (London) asked if it was right to say that however much calcium was put in it was washed out at increased rate. *Sir Reginald Watson-Jones* (London) asked if we should abandon giving Dienoestrol, vitamin D and calcium. Dr Urist replied that the difference with isotope and tetracycline labelling was due to inexperience with the tetracycline technique, which gave a high reading. Balance studies were carried out on a diet as near to the family one as possible. He was uncertain if there was much difference between the osteoporosis in the tibia and the spine. He assumed the disease to be generalised. He agreed that however much calcium was put in more was washed out. There was no danger in large amounts of calcium in the diet if combined with ample fluids. The value of hormones was doubtful.

Bone biopsy in the study of metabolic bone disease—*Dr S. W. Stanbury* (Manchester) said that his paper was concerned with metabolic disease associated with defective skeletal mineralisation, and bone biopsy was a convenient method of establishing these changes. He had studied 1) renal osteodystrophy, 2) familial hypophosphataemia or so-called vitamin-D-resistant rickets or osteomalacia, and 3) hypophosphatasia. These were more common than was generally believed. Diagnosis of osteomalacia had been made from histological appearances and not from blood chemistry. In osteomalacia the amount of osteoid was greatly increased in relation to the mineralised bone. Chronic uraemia in animals produced only the changes of osteitis fibrosa, but in man it caused typical osteomalacia like renal rickets. These changes could be reversed by the administration of large doses of vitamin D. Sometimes biopsy showed osteomalacia in the presence of sclerosis, but he could not explain this. The metabolic pattern mimicked almost exactly the state of the external calcium and phosphorus balances in nutritional rickets. The curative response to vitamin D occurred whether or not the acidosis was corrected. Very large doses of vitamin D were necessary, even up to 500,000 units daily. Renal disease seemed to produce resistance to the biological action of vitamin D, and vitamin D would reverse the changes of secondary hyperparathyroidism. Rachitic changes were present in childhood but settled, leaving no more than the typical minor curve of the tibia. The disease had a latent period until late middle age when symptoms of pain in joints and spine developed with osteoarthritic changes. The skeleton became sclerotic but biopsy showed the presence of osteomalacia. Occasionally changes like those of ankylosing spondylitis were found. The condition responded to vitamin D. He also

emphasised the phasic activity often found in hypophosphatasia. *Sir Reginald Watson-Jones* (London) asked if there was any danger in giving 500,000 units of vitamin D. Dr Stanbury said that there was danger. He had not yet met any metastatic calcification in the kidney or arteries, but he thought it wiser to accept improvement rather than to carry through to a cure. Then the risk was small.

Congenital dislocation of the hip—*Mr T. G. Barlow* (Manchester) stressed the importance of early diagnosis and mentioned that in Malmö von Rosen had routinely examined all children at birth and was able to claim that no new case of dislocation had been found since these examinations began. Since June 1957 he had examined 7,452 children in the first week of life born at the Hope Hospital, Salford. About 2,700 of these children had been re-examined at the end of one year. The Ortolani "click" test had proved satisfactory in children about a year old but unsatisfactory in new-born children. He described a modification of this test which he had devised and which he had found to be better. Plain radiographs with the legs together were of little value. Radiography with the hips abducted 45 degrees as described by von Rosen was useful, but it was not possible to radiograph all new-born children. The finding of limited abduction was a satisfactory sign only in older children, when adaptive shortening of the adductors had taken place. Asymmetrical skin folds were of no value. No seasonal incidence had been found. The only abnormal intra-uterine position which was of significance was the breech presentation: 4·5 per cent of the normal children were delivered from breech presentations but 20·4 per cent of those with abnormal hips. Birth weight was of no significance nor was the position in the family. In the 7,452 children examined within one week of birth there were 114 abnormal hips, sixty-four dislocated and fifty unstable, an incidence of one in seventy-six. Analysis of those that were found to be abnormal in the first week showed that there must be a 54 per cent recovery in the first three and a half days. Of the original 114 abnormal hips 102 had, with or without treatment, become stable within two months and when radiographed at one year were normal. The remaining twelve presented an incidence of one in 600. He had found no evidence to suggest that in any child dislocation developed later than at the time of birth. He described a new and improved type of malleable splint. It had proved impossible to say which hips would undergo spontaneous recovery and it was therefore better to treat all that showed abnormality as soon as possible. *Professor Bryan McFarland* (Liverpool) congratulated Mr Barlow and emphasised the importance of early diagnosis. He thought the Ortolani sign and limitation of abduction were unreliable in the early days. Mr Barlow said that his test for instability had not let him down in 5,000 examinations in the new-born. He had found that instability of the hips could get better but never got worse.

Femoral anteversion—*Mr J. A. Wilkinson* (London) said that in a previous investigation he had noticed the absence of anteversion in the hips of children treated in the Lorenz position. He had carried out a series of experiments in which young rabbits' hips were splinted in medial or lateral rotation. The former caused anteversion and the latter retroversion. Splinting in the Lorenz position corrected both. Splinting in medial rotation also caused failure of development of the anterior lip of the acetabulum. The mechanism whereby the Lorenz position caused correction was described. *Mr J. S. Batchelor* (London) pointed out that splintage in his plasters in medial rotation allowed circumduction and was not a fixed position. *Dr Carl Badgely* (Ann Arbor) emphasised the importance of early diagnosis. He thought that all Mr Wilkinson had shown was the extraordinary adaptability of bone to its environment. The hip was primarily normal; the changes that developed were due to faulty environment. *Sir Harry Platt* (Manchester) said that he did not worry about anteversion as it rarely needed correction by derotation osteotomy. The hip would adapt itself. *Mr J. C. Scott* (Oxford) said that many hips were unstable after treatment in the Lorenz position because of persistent anteversion. The medially rotated position did no harm if not maintained too long. *Mr G. P. Mitchell* (Edinburgh) said that Ortolani's click was of little value in the new-born. In the very early stages the simplest method of treatment by abduction was all that was required. At this stage the displacement was seldom more than a subluxation. *Mr H. J. Seddon* (London) said that in the days when the Lorenz was the standard position anteversion was of little significance; it had become a problem requiring osteotomy only since the introduction of the medially rotated position. *Mr H. Osmond-Clarke* (London) said that the old position of anterior reposition which was at one time considered to be desirable was nothing more than anteversion of the femoral neck. *Mr D. Trevor* (London) thought that anteversion was an important factor and that osteotomy for its correction would in future be done increasingly often. Mr Wilkinson, closing, said that anteversion was not present at birth in dislocated hips. Elasticity of the capsule was present in all boys and 25 per cent of girls and hormonal laxity in 75 per cent of girls.

A review of Morton's metatarsalgia—*Mr W. Sayle-Creer* (Manchester) had operated on 129 feet where a diagnosis of Morton's metatarsalgia had been made. The lesion was most commonly in the 3–4 cleft. The findings in order of frequency were fibroma, soft-tissue tumour, fibroma plus soft-tissue

tumour, a dry adherent nerve and no abnormality. Histologically the affected nerves showed evidence of endarteritis obliterans. He had observed that the condition was becoming less frequent in Manchester. A film demonstrated the operative technique. *Mr K. I. Nissen* (London) agreed with the method of treatment and the histological changes. The trouble was caused by restriction of the normal spread of the forefoot in closed footwear; this caused the intermetatarso-phalangeal bursa to bulge fowards and stretch the dorsal communicating artery, leading to a tension lesion at its point of anastomosis with the plantar digital vessels.

Population studies in Dupuytren's contracture—*Mr P. F. Early* (Manchester) had reviewed the employees at a large engineering works, a cross-section of the population of an industrial and mining town, the inhabitants of an old people's home, and patients in an epileptic colony. There was no doubt that the incidence increased with age. Contracture was commoner in men than in women, and he had found no evidence that manual work increased the incidence or affected the course. Dupuytren's contracture was undoubtedly more common in epileptics than among the general population, and was more frequently bilateral. The cause for this was uncertain but it had been suggested that the taking of phenobarbitone might be a factor. He had not found any connection between Dupuytren's contracture and any other disease. *Mr Harold Richards* (Cardiff) asked if he had compared the incidence in epileptics in a colony with those at home. Mr Early replied that there was no difference in incidence between the two groups.

Occult forms of spinal dysraphism—*Mr Michael James* and *Mr L. P. Lassman* (Newcastle upon Tyne) said that in spina bifida of any degree cord changes could develop. Changes occurred in the feet which might be mistaken for those of club foot or old poliomyelitis. The foot became cavo-varus and there might be shortness of the leg. Reflex and trophic changes might develop. Sensory changes were slight. The onset was often gradual and it did not become apparent until the age of four to six years. The invertors were overactive and caused cavo-varus deformity. Progress might cease but it might go on to paraplegia with incontinence. In diagnosis myelography was essential to show the site of the lesion and to demonstrate the level of the conus. When this was below the level of L.3 it was pathological, and operation should be undertaken to prevent further deterioration. Twenty-four laminectomies had been undertaken. Traction bands, pressure from diastematomyelia, or a combination of the two were found to be the responsible factors. Although operation had been undertaken mainly to prevent progress they had found improvement in two-thirds of the patients. *Professor C. E. L. Allen* (Cape Town) asked if twin births had been found in the families and if the changes found represented an ectodermal dermoid. Mr James said he did not know. *Mr H. A. Kidd* asked if the leg was short or the foot small. Mr James replied that sometimes the foot was small with a normal leg and sometimes the reverse.

Surgery of the foot in leprosy—*Mr A. H. G. Murley* (London) said that leprosy was still a very common disease. There were more than 10,000,000 patients requiring treatment. He had reviewed 500 such patients in Hong Kong. The chief cause of ulceration was peripheral neuritis which also caused muscle weakness. Foot drop occurred in 15 per cent and foot ulceration in 11 per cent. Complicating pyogenic osteomyelitis might cause great destruction. Gross deformity might follow an acute lepromatous reaction, which could develop at any stage of treatment and last for days or months. The patient was very ill. In the foot osteoporosis was rapid and extreme and weight bearing caused destruction of the tarsal bones. If weight bearing was avoided resolution occurred, but often persistent fibrosis increased the likelihood of ulceration and the foot might become fixed and deformed without proper care. Medical treatment would help to prevent deformity but since leprosy caused intraneural fibrosis it was difficult to see how surgery could help. Nevertheless in the acute stage, if steroids did not relieve the paralysis in six hours, the nerve should always be decompressed. The value of this had not yet been fully assessed. Prevention of deformity was better than cure, and the education of the patient to avoid sores and prevent secondary infection was essential. Deformity must be treated. Claw toes could be fused. Drop foot responded well to transplant of the tibialis posterior to the dorsum of the foot, and equino-varus deformity should be corrected by bony operation. The blood vessels were often constricted and extensive bone resection might be necessary to avoid gangrene through tension. Amputation was sometimes necessary but fitting a prosthesis was an unsolved problem so far.

The incidence of osteoporosis in patients with fracture of the neck of the femur—*Mr Jack Stevens*, *Mr P. A. Freeman*, *Dr Ellis Barnett* and *Dr B. E. C. Nordin* (Glasgow) said that most orthopaedic surgeons who treated patients with fractures of the femoral neck had the impression that the quality of the bone in these elderly patients was less good than in younger patients. But there had hitherto been no way of measuring the degree of osteoporosis. They had devised two methods. The first was by taking a standard biopsy of the iliac crest. This was compared with nine recognised standard

specimens of bone, so that the degree of osteoporosis might be estimated. The second method was based on radiographic measurements of the cortex of the femur and in the hand, and the depth of the body of the third lumbar vertebra. One hundred and thirty patients with fractures of the femoral neck or trochanteric fractures were investigated in these two ways. In 41 per cent osteoporosis was diagnosed and 59 per cent were considered to be within normal limits: 63 per cent of patients with trochanteric fractures were osteoporotic but only 40 per cent of those with transcervical fractures. This was significantly higher than the changes found in the controls. There was a well marked discrepancy between the two methods used but it was uncertain why this was so. *Dr Marshall Urist* questioned whether the changes in cancellous bone were the same as those in cortical. Unless in lateral views of the spine ballooning of the discs, collapse of bodies and thinning of cortex were present a definite diagnosis of osteoporosis could not be made. Of patients with fractures of the femoral neck 79 per cent showed some collapse of the vertebral bodies. To be of value, biopsy should be from tibial cortex, the thickness of which could be easily measured. Mr Stevens agreed that the nine-grade biopsy method presented difficulties which they were trying to correct, but he contended that the criteria mentioned by Dr Urist indicated a severe degree of osteoporosis. They were attempting to make the diagnosis at an earlier stage.

Fractures of the pelvis involving the floor of the acetabulum—*Mr E. J. Hargadon* and *Mr J. R. Pearson* (Manchester) reported their findings in a review of eighty patients who had sustained fractures of the pelvis involving the acetabulum. These had all been caused by a blow on the greater trochanter. They divided them into three grades: 1) minimal fracture not at first sight involving the acetabulum; 2) the same type of fracture but with the acetabulum obviously involved; and 3) central dislocation. In the first group treatment was by rest in bed for one to six weeks: 40 per cent had no ill effects; 35 per cent had moderate symptoms. In the second group treatment was by Russell traction for three to six weeks and the results were the same. In the third group it was noticeable that those in whom manipulative reduction was undertaken were the worst. The technique by which these fractures could be produced and studied was described. *Mr J. N. Wilson* (London) said that there was a type of fracture in group 3 in which the acetabular roof remained intact and in which the femoral head was dislocated forwards or backwards. In this type the displacement could be reduced with advantage and the instability helped by open operation. *Mr Harold Richards* (Cardiff) asked if oblique radiographs were taken routinely to show the fracture in group 1, and if group 3 in women caused any trouble in labour. Mr Hargadon replied that routine oblique radiographs were not necessary because the typical fracture seen could be assumed to involve the acetabulum. He had no knowledge of the effect of central dislocation on labour.

Fractures of the femoral shaft in adults—*Mr J. C. Scott* (Oxford) reviewed 282 fractures of the shaft of the femur treated at Oxford—forty-three pathological, fifty-one compound and 188 simple. Fourteen patients died, 188 were treated conservatively and thirty-seven by open operation. Routine treatment of the simple fractures was by Thomas's splint with skin or skeletal traction, and after one week a decision was taken about operation. Later a spica was applied in 37 per cent. Femoral fractures represented one admission in fifty to the Accident Service in the nine-year period under review; with this method of treatment they made up 30 per cent of the total bed days. In 146 cases union occurred in an average of 13·9 weeks and in thirty cases in 15·3 weeks. Forty-two operations were done with three amputations when the damage was very severe. Whether this fracture was simple or compound 80 per cent of patients were back at work in four to six months. In eleven cases shortening was one inch or more. Knee function was good when union was early and the knee not damaged. When the knee was stiff quadriceps-plasty was a good operation. It had been done nine times. Conservative methods gave 80 per cent of good results, and open operation should not be done unless clearly indicated.

Multiple injuries mainly involving the lower limbs—*Mr G. Murdoch* (Dundee) reported 362 fractures of the shaft of the femur. Of these twenty-two had been nailed. He advised against nailing when head injury was a complication or when the fracture was in the lower half of the femur. Nailing was most helpful when there were fractures of the tibia or knee on the same side as the fractured femur and when both femora were fractured. Retrograde nailing was best. The advantages were easier management, better knee function and better bony union. *Mr Harold Bolton* (Stockport) strongly advocated the postero-lateral approach for nailing, which gave better knee function than the anterior approach. *Mr A. L. Eyre-Brook* (Bristol) agreed with the value of the Küntscher nail in the right case. He advised against immediate operation but thought that it should be undertaken within one week and the nail must be big enough. *Mr John Charnley* (Manchester) said that if the operation was deliberately postponed for fourteen days there was less delay in union. *Mr F. C. Durbin* (Exeter) said that excessive

comminution could be controlled by circlage and a nail then used. He recommended a retrograde guide wire and introduction of the nail from above. *Mr H. Osmond-Clarke* (London) said that the Küntscher nail was good unless it was misused. Ideal conditions were necessary. *Mr G. Osborne* (Liverpool) asked if routine reduction should be carried out under general anaesthesia. The Thomas's splint was not a means of reduction but of retention. Skin traction was better than skeletal traction. *Professor Roland Barnes* (Glasgow) said that he disagreed with Mr Charnley's policy of waiting. Stabilisation was often urgently required. Mr J. C. Scott said that head injury was an indication for nailing. He agreed with the postero-lateral approach. Timing presented a problem. These were not killing injuries and on general grounds he waited seven to ten days. He was opposed to circlage but liked introducing the guide wire from below and the nail from above. He carried out routine reduction under general anaesthesia. Mr Murdoch stressed that in his series nailing was only done when indicated by special circumstances. He used the postero-lateral approach. The operation should be done quickly with a guide wire and the nail need not be an exact fit.

Treatment of displaced subcapital fractures of the femoral neck in the aged by immediate replacement arthroplasty—*Mr Harold Bolton* (Stockport) said that immediate replacement arthroplasty was the method of choice in very old patients with fractures of the femoral neck. He had done the operation eighty-eight times. For the first nineteen he had used Stamm's prosthesis but he had found the Austin Moore prosthesis better and had used it since. The operation was not done as an emergency. It was done under general anaesthesia with the patient prone, through a transverse incision along the line of the lower border of gluteus maximus. In opening the joint the obturator internus must be preserved. The length of the femoral neck must be maintained to make the head a tight fit when reduced. Among the complications there was sepsis in fifteen—severe in three—and dislocation in three. Eleven patients died from pulmonary embolism or coronary thrombosis. The great advantage was that walking could be started as soon as the wound was healed. *Mr J. C. F. Cregan* (Manchester) had found that the Austin Moore prosthesis was better than the Judet type, which he had used in primary treatment some years ago. *Dr Carl Badgely* (Ann Arbor) said that the incision described was dangerous and often led to sepsis. He preferred the lateral approach which gave a better exposure with less risk of fracture of the femoral shaft.

Clinical Meetings

At a clinical demonstration at the Manchester Royal Infirmary over a hundred patients were shown. The work of most of the orthopaedic departments in the region was represented. Demonstrations of general interest were presented by Mr D. Lloyd Griffiths and his team from the Department of Orthopaedic Surgery in the University of Manchester, who had also arranged a display of transparencies illustrating twenty tumours of bone and soft tissue. Patients were shown by Mr C. H. Cullen, Mr A. Glass and Mr F. Robinson from the North Manchester hospitals; by Mr J. C. F. Cregan and Mr O. O. Cowpe from the South Manchester hospitals; by Mr T. E. McSweeney from the South Cheshire Hospitals; by Mr S. M. Milner from the Bolton Royal Infirmary; by Mr V. H. Wheble from Ashton-under-Lyne General Hospital and by Mr W. Sayle-Creer and Mr T. G. Barlow from the Salford Royal Infirmary.

Patients were also brought from Stockport by Mr H. Bolton, and from Oldham by Mr T. K. Mukherjea. Mr P. F. Early and Mr P. Seelig, Manchester Limb Fitting Centre, demonstrated prosthetics used in the treatment of lower limb deformities.

There was also a demonstration of old books of orthopaedic interest from Manchester University Medical Library, arranged by the librarian, Mr G. Wilson, M.A. Display panels had been prepared by Sir Harry Platt on the long-term follow-up of congenital dislocation of the hip, by Professor J. H. Kellgren, Dr J. S. Lawrence and Dr R. G. W. Ollerenshaw illustrating standard radiographs in arthritis, and by Mr D. Lloyd Griffiths on eosinophilic granuloma in bone, among many others.

The clinical demonstration at Wrightington Hospital was presented by *Mr John Charnley*, *Mr K. L. Barnes* and *Mr R. S. Garden*.

Mr John Charnley presented a series of patients in whom Fluon arthroplasties had been done. The patients suffered from either rheumatoid arthritis or advanced osteoarthritis of the hips. A film of each patient before operation was shown (all were severely crippled). The patient was then demonstrated post-operatively climbing steps, walking and showing the range of movement. The remarkably normal gait was clearly seen. The follow-up was from eight to fourteen months. A simple ballistograph was demonstrated. On this apparatus the patient's gait was represented graphically so that normal and abnormal gaits could be studied. The new biomechanical laboratory was on view and several interesting machines were shown for estimating friction and wear in different materials. One gave a graphic demonstration of the degree of friction in a hip arthroplasty using an

Austin Moore prosthesis as compared with the friction in a Fluon arthroplasty in patients of similar weight.

Mr K. L. Barnes showed a series of patients with osteoarthritis of the hip in whom McMurray's osteotomy had been carried out with and without internal fixation.

Mr R. S. Garden presented an exhibit on internal fixation of fractures of the neck of the femur. The Küntscher low angle nail was demonstrated. He also showed a short threaded low angle nail of his own design with the instruments for its introduction and radiographs of hips in which it had been used. Two patients with osteoarthritis of the hip were shown in whom the psoas tendon had been divided.

REVISED ARRANGEMENTS FOR MEETINGS IN 1962

Attention is called to the Announcement on page 616 about the revised arrangements for Meetings of the British Orthopaedic Association in 1962.

ROBERT JONES GOLF CUP

The Annual Competition for the Robert Jones Golf Cup was played on April 12 at the Manchester Golf Club in poor weather. A mixture of wind and rain made play difficult but the holder, Mr W. E. Scott of Market Harborough, mastered the conditions and again won with a score of 75 from scratch. The runner-up was Mr J. H. Shelswell of Southend-on-Sea with a net score of 78 off a handicap of 14.

ROYAL COLLEGE OF SURGEONS OF ENGLAND

ELECTIONS TO COUNCIL

Mr Norman Capener was among the five Fellows of the Royal College of Surgeons of England elected to the Council in July, 1961.

SCIENTIFIC SOCIETIES AND REGIONAL ORTHOPAEDIC CLUBS

THE BONE AND TOOTH SOCIETY

A meeting was held at the Institute of Orthopaedics, Royal National Orthopaedic Hospital, 234 Great Portland Street, London, W.1, on April 19, 1961.

The parathyroids and vitamin D in calcium homeostasis—*Dr Franklin C. McLean* (Chicago) said that parathyroid physiology had entered a new era in 1960, with the isolation and characterisation of a pure parathyroid hormone from bovine sources by Rasmussen and Craig (*Journal of Biological Chemistry*, 1961, **236**, 759). The hormone was a single chain polypeptide with a molecular weight of $9{,}500 \pm 100$, and was homogeneous to chromatography, ultracentrifugation and countercurrent distribution. Its composition was known in terms of its amino-acid content, there being approximately 83 amino-acid molecules in the chain. With use of the new preparation, evidence was accumulating that: 1) the parathyroid glands elaborated only one hormone, with both calcaemic and phosphaturic properties; 2) use of the preparation, in patients or in experimental animals, did not lead to resistance to its physiological effects; it might be used for replacement therapy over a long period of time in hypoparathyroidism, and to produce chronic hyperparathyroidism in experimental animals; 3) no haemodynamic effect upon glomerular capillary circulation was observed.

Copp was clarifying the problems of parathyroid secretion by a refinement of the methods introduced by Hastings and Huggins and by Patt and Luckhardt before 1940. Copp's most recent work (unpublished) appeared to afford definite evidence that the parathyroid glands themselves acted both to receive information concerning the plasma level of Ca^{++} and to apply the necessary corrections by regulating the release of calcium from the skeleton. Copp's work added support to the concept of a dual mechanism for homeostatic regulation of the Ca^{++} concentration in the plasma, introduced by McLean and Urist in 1955.

McLean and Hastings had, in 1935, described the calcium in the blood plasma as a solution of calcium proteinate, dissociating as a weak electrolyte, so that approximately half of the serum calcium remained in an undissociated complex with the serum protein, while the other half was mainly in the form of free and physiologically active Ca^{++}. This concept had stood the test of time, but both G. Alan Rose and Smith Freeman, working independently, and with results in part as yet unpublished, had found reason to believe that the affinity of protein for calcium was increased in hypercalcaemic animals. Rose attributed this to a direct influence of the parathyroid hormone on the calcium-protein relationship, while Breen and Freeman (*American Journal of Physiology*, 1961, **200**, 341) observed the same effect when calcium was added *in vitro* to the hypocalcaemic serum of hyperparathyroidism. Because McLean and Hastings, Rose, and Freeman had all used different methods, the differences in their results awaited clarification.

As to the mode of action of the parathyroid hormone, nearly all observers were now agreed that there was a direct action on bone, controlling the release of calcium to the circulating fluids of the body. There were, however, differences in interpretation of the observed results. McLean and Urist had assumed that calcium from the labile or reactive fraction of bone was available by passive ion transfer, and that the parathyroid hormone acted by regulating osteoclastic resorption, mainly of stable, non-reactive bone. Neuman, however, and also Nordin, emphasised the role of lactic acid, formed in the glycolytic cycle, in rendering the reactive bone mineral soluble and in transferring it to the circulating fluids. Here again further clarification was needed. With the advent of the new era in parathyroid physiology it seemed that these and many other problems concerning the effects and mode of action of the hormone were approaching solution.

Terepka, Dowse and Neuman (*United States Atomic Energy Commission UR*—577, 1960) had recently introduced a unifying concept of the action of the parathyroid hormone on the known target organs: bone, kidneys, gastro-intestinal tract, and the lactating mammary gland. This concept brought all these actions within a single framework, depending upon the transfer of phosphate by cells. Rasmussen (*American Journal of Medicine*, 1961, **30**, 112) had also introduced an integrated concept but at the organ system level rather than at the cellular level explored by Neuman.

It was now generally accepted that vitamin D also played a part in the mobilisation of calcium from the skeleton, although less attention had been given to the details of the mode of its action on bone. An oversimplified version of this would be to say that vitamin D exerted its influence in proportion to the amounts present in the organism, and that the parathyroid glands, which were responsible for monitoring the Ca^{++} concentration in the plasma, added to the effect of vitamin D and thus maintained the Ca^{++} level within normal limits. In this respect, vitamin D and parathyroid hormone were synergistic in their effects.

EAST ANGLIAN ORTHOPAEDIC CLUB

A meeting of the East Anglian Orthopaedic Club was held at St James' Hospital, Kings Lynn, on Saturday, November 26, 1960. The clinical demonstration was arranged by Mr A. B. King.

Children with congenital deformities—*Mr A. B. King* began by showing a number of children with congenital deformities, the first having a hemi-vertebra and asymmetry of chest with the lung and diaphragm bulging through a defect in the chest wall. In the discussion it was generally agreed that operation should be delayed.

Mr King then showed a number of children with varying numbers of digits. On one child, with an absence of thumb, a successful rotation osteotomy had been done but had left the child with an abnormally long "thumb."

A child of twelve was then shown who had numbness on the outer side of the thigh and muscular wasting of all four limbs. The spine was mobile but there were café-au-lait spots. He had been investigated under Sir Russell Brain but no evidence of a spinal tumour had been found. The condition of the child was deteriorating, pigmentation was increasing and flexion deformities were occurring. Various diagnoses were suggested by members.

Slipped femoral epiphyses—*Mr A. B. King* next showed a series of slipped femoral epiphyses. In one the Smith-Petersen nail had become displaced but because sufficient fusion had taken place no further operation was necessary; in another a subtrochanteric osteotomy had been successful, but in a third, after an osteotomy at the base of the neck, an adduction deformity had developed necessitating an arthrodesis which was successful. Finally a child was shown for whom operation had been refused and who had been treated successfully in a hip spica.

Fractured scaphoids—*Mr S. K. Ghosh*, surveying the results of treatment of recent fractured scaphoids, had found that the average length of time necessary to get bony union was nine and one-quarter weeks but that two scaphoids took as long as six and fourteen months. There was general discussion on this subject and many variations in treatment were recommended.

Hyperparathyroidism—*Mr A. B. King* showed a girl with a painful swelling over the tibia which showed as an area of tibial rarefaction in the radiographs, with many similar lesions throughout the skeleton. This was thought to be due to hyperparathyroidism. The thyroid was explored and a small tumour removed.

CANADA

THE ROYAL COLLEGE OF PHYSICIANS AND SURGEONS OF CANADA

ELECTION OF SIR WALTER MERCER TO HONORARY FELLOWSHIP

At the annual Convocation of the Royal College of Physicians and Surgeons of Canada in Ottawa on January 20, 1961, Sir Walter Mercer received the Scroll of Honorary Fellowship from the President, Dr Donald A. Thompson. At the same Convocation His Excellency Major-General Georges Vanier, Governor-General of Canada, was also made an Honorary Fellow of the College.

Sir Walter Mercer receiving the Scroll of Honorary Fellowship from the President of The Royal College of Physicians and Surgeons of Canada. Seated behind is His Excellency Major-General Georges Vanier, Governor-General of Canada.

ALEXANDER GIBSON LECTURE

Sir Walter Mercer gave the first Alexander Gibson Lecture at the University of Manitoba on January 24, 1961. He took as his title " Edinburgh and Early Canadian Medicine."

Sir Walter first outlined Gibson's career, recalling that he had been born in Edinburgh in 1883. He had shown great distinction as a student at Edinburgh University, where he had graduated in 1908. In 1913 he had been appointed Professor of Anatomy in Manitoba Medical College, but interrupted his career to serve in the armed forces during the first world war. Later he was appointed to the Chair of Orthopaedic Surgery in the University of Manitoba.

Sir Walter then traced the early history of medicine in the different Provinces of Canada. It began in the seventeenth century, when there was a great influx of immigrants from Britain, and especially from Scotland. The early practitioners of medicine were mostly untaught and often little better than charlatans. The only method of training was by apprenticeship. Later there was a considerable influx of men who had graduated and trained in Scotland.

Sir Walter went on to describe the formation of the first Canadian School of Medicine, in Montreal. James McGill had graduated at the University of Glasgow and settled in Montreal when it was a town of only 9,000 inhabitants. When he died in 1813 he left part of his fortune for the foundation of the now world-famous McGill University. This received its Charter from George IV in 1821. About the same time the building of the Montreal General Hospital was begun. Four of the original six members of the staff of the Faculty of Medicine were Edinburgh men. They started the Medical School with a class of twenty-five students, the first lectures being given in 1824. The organisation and methods of teaching were based on those of the Edinburgh school, and there was much similarity between the Montreal General Hospital and the Edinburgh Royal Infirmary. The University and the Hospital flourished, and as early as 1860 the medical students under training numbered 108.

The development of l'Université de Montreal was considerably later. It was incorporated in 1920 by the union of l'Ecole de Médicine et Chirurgie de Montreal—founded in 1843—with l'Université de Laval. Again many of the staff of the School had graduated in Edinburgh.

In Ontario the earliest doctors were surgeons of British regiments who cared for the civilians living close to the garrisons. Some of them remained upon their retirement from the Army. Notable among the pioneers who settled at York, the capital of the Province, were James McCauley, the Irishman John Gamble, and William Baldwin—all graduates of Edinburgh University.

CANADIAN ORTHOPAEDIC ASSOCIATION

The sixteenth annual meeting of the Canadian Orthopaedic Association was held at Saskatoon from June 18 to 22, 1960.

Non-tuberculous narrowing of intervertebral disc spaces in children ("spondylarthritis")—*Dr F. R. Tucker* (Winnipeg) described six children under five years old with non-tuberculous inflammatory disease involving the intervertebral disc. His interest lay in the relatively benign clinical course. The children presented with fever, spasm of the erector spinae muscles, and pain sometimes referred to the abdomen or hip. There was a raised sedimentation rate but leucocytosis was not marked. Agglutination tests and blood cultures were negative, and specimens obtained by punch biopsy in two cases were sterile. The children did well with rest and mild sedation. Antibiotic treatment did not appear to affect the course of the disease; the narrowing of the intervertebral disc remained after apparent cure. *Dr J. C. Favreau* (Montreal) thought that this was probably a bacterial infection modified by the young age of the patients.

Recurrent lumbar disc protrusions—*Dr E. S. James* (Winnipeg) gave his experiences with operations upon 117 patients with recurrence of herniated intervertebral discs after a previous operation. Two-thirds were true recurrences from discs previously explored. One-third were not true recurrences because the herniation was at a different level. The difficulty in localising a new herniation was emphasised, and spinal fusion was advocated in treatment.

The spine in multiple myeloma—*Dr Sidney P. Traub* (Saskatoon) reviewed the early symptoms and signs—and related them to the difficulty of early diagnosis—in seventy-three patients suffering from myelomatosis who were admitted to the Saskatchewan Cancer Clinic over a nine-year period. Low back pain, persistent and progressive, was the usual presenting symptom. Radiographs of the spine in 60 per cent showed only a diffuse non-specific osteoporosis with or without poorly defined destructive lesions. Biconvex widening of the intervertebral disc was common. In seven patients the radiographs were entirely normal. The suspicion of myeloma was increased by an elevated sedimentation rate. A skeletal survey usually demonstrated a destructive lesion.

Human posture—*Dr W. H. Fahrni* (Vancouver) said that the "military stance" of western man demanded a lordosis of the lumbar spine. Admonishing the young to stand straighter might cause an increase of this. Associating lordosis with the clinical observation that degenerative change in the spine tends to occur first and to the greatest degree on the concave side of any spinal curvature, Dr Fahrni had observed the postural habits of a primitive tribe of Indians, the Bhils, in the far east. Unconditioned by western custom, this tribe maintained their lumbar spines in a straight or flexed posture, assuming a lordosis rarely and for short periods only. The local hospitals testified to the rarity of low back pain and sciatica in this group, but a large scale radiographic survey had not been carried out to discover the incidence of degenerative change.

One-stage pantalar arthrodesis—*Dr G. W. D. Armstrong* (Ottawa) described an operation that had been successful in producing a pantalar arthrodesis in a small series of adult cases. The combined operation did not add greatly to the operating time for either an ankle fusion or a triple arthrodesis, and accomplished both at one sitting. Compression was used to maintain bone apposition.

A method of hindfoot stabilisation—*Dr W. J. S. Melvin* (Kingston) disliked the squat appearance of a foot in which a triple arthrodesis had been done by excision of joint space. To avoid this shrinkage due to tissue removal and at the same time to promote bony fusion, he recommended crossing the joint lines with massive bone blocks cut from the iliac crest. He had borrowed the principles of Gallie and Grice. Evidence from follow-up examinations in eight cases showed that the method was successful. There was a gradual melting away of the joint cartilage and a merging of the bony structures. In children, however, Dr Melvin was not entirely convinced that he had not interfered with bone growth.

Osteotomy of the calcaneum in the treatment of pes cavus—*Dr J. Robichon* and *Dr F. A. Ducharme* (Ottawa) reviewed the mechanisms supposedly responsible for pes cavus. They had discarded primary operative attack upon the forefoot and had adopted the Dwyer procedure, which they had used in nine feet with satisfactory early results.

Os intermetatarseum and a possible relationship to hallux valgus—*Dr R. S. Henderson* (Edmonton) had encountered, in two members of the same family, an odd accessory ossicle lying between the bases of the first and second metatarsals. The ossicle seemed to be at least partly responsible for marked hallux valgus in the same foot. Dr Henderson thought this ossicle might represent an anomalous extensor hallucis brevis muscle, because a fibrous continuation of the ossicle was inserted into the lateral side of the base of the proximal phalanx of the great toe. Excision of the ossicle and the band considerably improved the medial flaring of the first metatarsal.

The history of Syme's amputation—*Dr R. I. Harris* (Toronto) said that divergent opinions were held throughout the world regarding the merit of Syme's amputation. A study of its development threw much light upon the operation and the qualities that were necessary for success. Syme had developed his operation in pre-anaesthetic and pre-antiseptic days. His success with Chopart's disarticulation led him to apply the same principle to the ankle. The stump after disarticulation was more resistant to infection than that from amputation; hence an ankle disarticulation was less dangerous than amputation. For functional success it required a covering capable of bearing weight, and Syme's genius devised a means of preserving the heel flap and reapplying it to the cut end of the stump for this purpose. In Syme's day many European surgeons struggled with the same problems of removing the foot with the least risk to life and covering the stump with an end-bearing flap. None of their procedures proved as successful as Syme's. Moreover, attempts to improve on Syme's technique had always resulted in an imperfect stump. Syme's original technique still gave a satisfactory end-bearing stump.

The uses of the Knowles pin—an important adjunct to the orthopaedic surgeon—*Dr D. R. Bigelow* (Brandon) discussed the technical advantages to be gained by the use of the Knowles pin.

Arthrodesis of the hip: a review of principles—*Dr D. E. Starr* (Vancouver) traced through the years the evolution of the methods now accepted for arthrodesis of the hip. He demonstrated pictorially the forces acting upon the hip joint and the effect of these forces upon grafts placed both centrally and peripherally. From clinical end-result studies he showed that ischio-femoral grafts, particularly if associated with femoral osteotomy, gave the highest percentage of success from a primary operation. Although the percentage of success was not so great for osteoarthritis as for tuberculosis, nevertheless the relative incidence of fusion remained much higher. *Dr J. R. Naden* (Vancouver) agreed with Dr Starr but believed that in osteoarthritis of the hip internal fixation of the joint in addition to a graft allowed early knee movement, which was not possible when the patient had undergone an osteotomy.

Present concepts in the treatment of scoliosis—*Dr John H. Moe* (Minneapolis), as guest speaker, drew from his extensive experience to discuss present concepts in the treatment of scoliosis. He reviewed the difficulties that he had encountered and suggested ways of avoiding these. The means of correction, the extent and method of fusion, and post-operative care formed the body of his address. Finally, he touched upon the possibilities of the Harrington apparatus with which he had had some experience.

Results of conservative treatment of fracture of the shaft of the femur—*Dr F. P. Patterson* (Vancouver) had studied 108 patients with fractures of the shaft of the femur, who had been treated conservatively by traction or by operation and a Küntscher nail. Open reduction entailed an increased risk of delayed union and there were a few cases of catastrophic infection. When Küntscher nails worked well they worked very well and were highly attractive. Closed reduction gave earlier evidence of union, did not entail any risk of infection, but posed the problems of knee stiffness, refracture and malunion. He believed that these complications were less numerous and less serious, and the overall picture of the study had encouraged him to treat fractures of the femur without open reduction.

Fractures of the proximal end of the femur in children—*Dr H. S. Cameron* (London) reviewed fourteen children with fractures of the proximal end of the femur. The injuries were all violent and in several children there were concomitant injuries. There was only one case of traumatic separation at the epiphysial line and it is interesting that this was reduced satisfactorily ten days after injury. The fractures were treated in a variety of ways. The poorer results were associated with internal fixation, but this was undertaken for the more serious fractures. Frank avascular necrosis was not seen but one hip showed severe arthritic changes. With conservative treatment two hips developed varus deformities. Dr Cameron concluded by saying that this was a fracture that should be treated with considerable respect, but he gave no definite opinion on the merits of conservative versus operative treatment.

Primary prosthetic replacement for subcapital fractures of the femoral neck—*Dr E. Lepine* and *Dr A. Thivierge* (Montreal) discussed the difficulties of establishing, and attempting to establish, satisfactory indications for initial replacement of the femoral head in the treatment of subcapital fractures. They believed that sixty-five was a critical age and those patients who were older should be seriously considered for the replacement operation, but, if there was doubt, nailing should be performed. Before one could say that a patient could afford six to twelve months in an attempt to obtain bony union or that it was a wise investment, the physiological age and economic factors had to be considered.

Treatment of fractures of the upper end of the femur by the Pugh nail—*Dr J. P. Moreau* (Edmonton) gave his experiences with the use of the Pugh nail for fractures of the femoral neck. The nail is designed to telescope and this attribute is of decided advantage in intertrochanteric fractures. Uncomplicated subcapital fractures, well reduced and nailed, gained no advantage. In this group the incidence of complications was, as always, high. A small series of patients with subcapital fractures, selected

because of difficulty in reduction and nailing, had been subjected to an osteotomy that allowed collapse of the head upon the neck. The result was promising in some cases but the procedure increased the overall mortality.

Innominate osteotomy—*Dr R. B. Salter* (Toronto). This paper is published in full in this issue of the *Journal of Bone and Joint Surgery*.

Teflon as a ligament substitute—*Dr O. Rostrup* (Edmonton) said that he had been stimulated in this research by the mediocre results of delayed surgical repair of torn ligaments about the knee. He reported upon an experimental study in dogs using Teflon replacement of the medial collateral and anterior cruciate ligaments.

The incidence of malignant bone tumours in Saskatchewan—*Dr E. A. Jones* (Regina) had noted that the population of Saskatchewan had altered very little numerically in regard to the total, the sex, or the age distribution between 1932 and 1959. Also 99 per cent of cancer patients came under review by the Cancer Commission. These facts lent value to a statistical study of bone tumours. Dr Jones felt that the incidence of osteogenic sarcoma increased with age. In the second decade it was one per hundred thousand age group population and in the eighth decade it was 7·24 per one hundred thousand. In thirty-seven proven cases from 1932 to 1954 one-third of the patients were dead at the end of one year; at the end of two years one-half were dead; at the end of three years two-thirds were dead; and at the end of five years 27 per cent survived. In the whole group of forty-eight patients five were alive and well ten years after treatment. All with long-term survival had had amputation with or without pre-operative radiation. Chondrosarcoma with less radical operative procedures showed a high local recurrence rate. At the end of the first year four-fifths of the patients were alive. At the end of the second year over 50 per cent were alive. At the end of the third year half, and at the end of the fourth year slightly less than half were alive. At the end of the fifth year six of the original twenty-one patients survived. There was not a sufficient number of cases of fibrosarcoma, periosteal osteogenic sarcoma, or Ewing's sarcoma to make statistical observations valid.

Bone changes in blood dyscrasia—*Dr B. J. S. Grogono* (Winnipeg) pointed out that many blood dyscrasias were accompanied by radiological evidence of change in the density, architecture and contour of bones. While these skeletal features of any disease were not pathognomonic, careful examination of the circulating blood and bone marrow was indicated. The altered appearance of bone in a variety of blood dyscrasias common in the western hemisphere was illustrated.

The importance of the anterior cruciate ligament in relation to tears of the medial semilunar cartilage—*Dr D. L. MacIntosh* (Toronto) had found a tear of the anterior cruciate ligament in 40 per cent of the knees operated upon for traumatic lesions of the medial cartilage in young adults. Such tears, if not accompanied by laxity of the medial ligament, were difficult to diagnose. However, the added freedom of movement of the femur on the tibia after a tear of the anterior cruciate ligament predisposed to the eventual tearing of the cartilage.

The use of the vastus intermedius tendon transplant after patellectomy—*Dr I. W. Davidson* (Toronto) and *Dr E. L. Jewett* (Orlando, Florida) recognised that the gap in the quadriceps mechanism left by patellectomy could not always be eradicated by suture, and they demonstrated how the vastus intermedius tendon could be used to fill the gap. This tendon, four to five inches long when separated from its origin, was turned downwards and sutured to the patellar tendon. Such a manoeuvre filled in the unoccupied area without altering the normal tension of the quadriceps mechanism. Thus, early knee flexion could be allowed without fear of stretching, and prolonged immobilisation in a straight leg position, with its possible sequel of knee stiffness, was avoided. The early results in three patients were shown.

Role of the parosteal tissue in the post-traumatic osteogenesis of long bones—an experimental study—*Dr L. Jarry* and *Dr H. Uhthoff* (Verdun) described experiments on rats in which they had endeavoured to distinguish between the role of the periosteal and the parosteal tissue of the limb in bridging a fresh fracture. They concluded that the parosteal tissues were of great importance and that their exclusion from the fracture jeopardised union; that parosteal tissue cells were induced by the presence of the fracture to assume osteogenic properties; and that specific osteogenic tissue did not exist.

Fractures of the tibial plateau—*Dr G. A. McDonald* (Toronto) presented the results of a clinical review over a ten-year period of seventy-seven cases of fractures of the tibial plateau. The fractures fell into two groups, stable and unstable. The stable group were managed satisfactorily by simple measures, such as aspiration of the joint, pressure bandaging, and temporary splinting followed by intensive muscle rebuilding. The unstable fractures, thirty-seven in number, were treated by open reduction and internal fixation, usually with a Barr bolt. The importance of accurate reduction, firm fixation and the support of the plateau by bone to fill the spaces left after elevation was stressed.

When this was accomplished early movement and muscle rebuilding were possible and the results were satisfactory. The indications for operation, the operative technique and an evaluation of the results were presented. Eighty-two per cent of the fractures treated by operation fell into the excellent or good group and 18 per cent into the fair group.

The etiology of chondromalacia of the patella—*Dr R. E. Outerbridge* (New Westminster). This paper will be published in full in a future issue of the Journal.

Patho-mechanics of intertrochanteric fractures—*Dr R. G. Townsend* (Montreal) demonstrated from a series of necropsy specimens the patho-mechanics of severe intertrochanteric fractures. He discussed the factors influencing the rate of healing and the possible causes of the common complications.

Intramedullary nailing for fractures of the tibia—*Dr M. Alms* (Saskatoon) demonstrated with a film the technique of intramedullary nailing for fractures of the tibia. He reviewed the results in the first fifty cases.

Engelmann's disease—*Dr M. G. Kunkel* (Saskatoon) showed a twenty-three-year-old woman who had radiological and pathological characteristics compatible with Engelmann's disease of the radial diaphysis. The disease was monostotic.

Aseptic necrosis of the distal tibial epiphysis—*Dr D. E. Robertson* (Saskatoon) showed a child with a persistent limp, pain and swelling about the ankle joint, of four months' duration. Radiographs revealed a " wafer biscuit " appearance of the lower tibial epiphysis. The child had been treated conservatively in a walking plaster for two months, and twenty-four months after the onset the ankle appeared normal clinically and was approaching normal radiologically. There was no apparent disturbance of growth.

Familial osteogenic sarcoma—*Dr E. A. Jones* (Regina), in the course of an extensive follow-up of osteogenic sarcoma in the Province of Saskatchewan, had found a familial incidence on two occasions. The first was of a father and son and the second of three siblings, two brothers and one sister.

Spinal fusion for tuberculosis—*Dr C. Robinson* (Saskatoon) approached the spine transpleurally after the method of Stock and Hodgson of Singapore. The lesions were decompressed, curretted and bone-grafted. In one patient there was a dramatic recovery from paraplegia. None of the cases was complicated by intrapleural sepsis. In all instances chemotherapy was used.

Vascular complications of gunshot wounds of the extremity—*Professor E. M. Nanson* (Saskatoon) related his experience in dealing with these complications, which were usually the result of shooting accidents. Many were associated with compound fractures. As in war wounds, gas gangrene was a danger. Early arterial exploration was advised and methods of dealing with the lesion were detailed. Caution was recommended in the use of anticoagulants.

Hyperthyroidism in polyostotic fibrous dysplasia—*Dr B. Bachynski* and *Dr H. J. Spooner* (Regina) described a ten-year-old Caucasian boy with polyostotic fibrous dysplasia. He had suffered multiple fractures from trivial trauma. The fractures healed without difficulty. On his admission the patient had a diffuse enlargement of the thyroid gland, a basal metabolic rate of plus 52 and a protein-bound iodine of 12·5 micrograms per cent. Hemithyroidectomy was eventually performed. It was thought that, in view of the frequent evidence of endocrine dysfunction in polyostotic fibrous dysplasia, the hyperthyroidism of this patient was not merely coincidental.

Cystic bone lesions—*Dr W. A. Costantini* (Saskatoon) reported three patients with interesting cystic lesions of bone. One of these turned out to be a simple cyst but the other two were due to chondromyxoid fibroma.

Girdlestone arthroplasty—*Dr C. B. Orchard* (Saskatoon) gave a short paper on the clinical aspects of five cases of hip disease that had been salvaged by the use of the Girdlestone procedure.

AUSTRALIA

AUSTRALIAN ORTHOPAEDIC ASSOCIATION

The Twenty-third Annual Meeting of the Australian Orthopaedic Association was held in Sydney on August 1–5, 1960, under the presidency of Mr R. McKellar Hall. The Association welcomed Professor Bryan McFarland of Liverpool, England, who was visiting Australia as guest lecturer under the aegis of the Postgraduate Committee in Medicine. It was also a pleasure for many at the meeting to renew the acquaintance of Mr Ross Nicholson of Auckland, New Zealand.

Presidential address—*Mr Brian Keon-Cohen* read the retiring president's address for *Mr Laurence Macdonald* who was abroad. It was a plea for simplicity, brevity and style in the writing of papers for publication in the journals. Too little effort was expended in making use of the clarity of the English language.

Osteoarthritis of the hip—*Professor Bryan McFarland* (Liverpool) showed a film of the " psoas release " operation for the relief of pain in osteoarthritis of the hip. Through an anterior approach the capsule of the hip, the ilio-femoral ligament, the direct head of the rectus femoris and the insertion of the psoas tendon were divided; an adductor tenotomy was done at the same time. The early results were promising.

Late results of McMurray osteotomy—*Mr T. King* and *Mr B. Dooley* (Melbourne) reported on forty-five non-consecutive patients, being all that could be traced, after McMurray osteotomies for osteoarthritis of the hip with unendurable pain, between 1938 and 1958. Internal fixation was used in thirty-four. Thirty-three patients had complete relief of pain for varying periods depending on the intervention of death, an incomplete follow-up or relapse after an average period of relief of nearly ten years. Six patients had complete relief for seventeen to nineteen years; thirteen from ten to fourteen years; four from six to nine years; and nine from two to four years. Thereafter there were five relapses between twelve and two years after operation. In three patients complete relief of pain did not take place until several years after the osteotomy. Non-union occurred three times; one after immobilisation in a spica and two after internal fixation. Three of the hips became ankylosed, and two of these also had non-union of the osteotomy. Infection of the wound and nail plate erosion developed in four. There were no serious complications from thrombosis or embolism. The average age at operation was fifty-four. It was considered that, although the best long-term operation in the under-fifty age group is arthrodesis, osteotomy still had a place in treatment.

Osteosarcoma—*Mr G. Kerridge* (Newcastle) surveyed 125 cases of osteosarcoma treated by members of the Australian Orthopaedic Association in the larger public hospitals in Australia. The survey was undertaken because of the widely differing figures found in the literature for five-year survival, despite the fact that the principles of treatment by amputation or radiotherapy were virtually the same everywhere. From the 125 cases reviewed a survival curve was prepared by Burkson's method and it was found that 60 per cent of the patients had died within one year of their first attendance at a doctor's surgery and 85 per cent had died within two years of their first attendance. The five-year survival rate was 8 per cent. It was found that the curve closely approximated to that of Sir Stanford Cade. The histories of the patients who survived five years and more were presented in detail and it was found that in all except two there were unusual features. Two patients had not had the clinical diagnosis confirmed by biopsy; in another case there was disagreement between the pathologists who examined the tissues; and in another there was difference of opinion between the pathologists and the clinicians and radiologists. Three patients showed long-term survival despite secondaries being present for some years. Mr Kerridge concluded by saying that osteosarcoma was a very fatal disease and, because the mortality rate in the initial two years was so steep, it was difficult to imagine that treatment made any difference to the mortality rate, but that some people survived for long periods with known secondaries. Not all survivors in survival curves were necessarily true survivors of the disease; and in this series a large number of patients were mutilated with little result. Palliation should be thorough, and should be directed against the symptoms from which the patient actually suffered. With such appalling results it was important not to be dogmatic, but to recognise how little we knew.

Lateral epicondylitis of the elbow—*Mr John Lahz* (Brisbane) described the treatment of this most refractory condition. He liked to infiltrate the extensor origin with Xylocaine, hydrocortisone and hyaluronidase as the primary treatment. When this failed he claimed consistently good results from division of the extensor origin. In the discussion *Mr A. R. Hamilton* (Sydney) extolled the virtues of acupuncture.

Ulnar neuritis—*Mr T. G. Hogg* (Launceston) recalled the original description of tardy ulnar palsy in 1887 by Dr Panas of Paris. The varied causes of ulnar neuritis were mentioned. In the treatment of late ulnar neuritis he preferred to excise the medial epicondyle, in preference to the customary anterior transplantation of the nerve. The operation was easy to perform and it involved negligible handling of the ulnar nerve or its branches. In the discussion *Professor Bryan McFarland* (Liverpool) pointed out that splitting the roof of the fibrous tunnel between the heads of the extensor carpi ulnaris gave immediate relief with even less effort.

Condylar fractures of the elbow—*Mr W. J. Betts* (Adelaide) said that for displaced fractures of the lateral epicondyle he preferred open reduction and fixation by chromic catgut suture, with immobilisation in a collar and cuff. He did not like plaster round the elbow and he had not encountered any failure of the fragments to unite after this type of fixation. In old ununited fractures with tardy ulnar palsy

he had secured relief from symptoms either by dividing the sheath of the extensor carpi ulnaris or by the classical anterior transplantation of the ulnar nerve. The widely displaced Y-shaped fractures he felt were best treated conservatively because a better functional range of movement was likely to ensue, rather than by attempting open reduction. In severely comminuted fractures of the condyles, such as occurred in " side-swipe " fractures, he emphasised that treatment should be directed to early movement.

Report of the Travelling Fellow for 1960—*Mr William Doig* (Melbourne) delighted the audience with a photographic record of this tour. The abundant hospitality and the lengths to which the American hosts had gone to impart their current practice and research activities were evident. Details of this tour have been fully reported in a previous number of this Journal.

Congenital dislocation of the hip—*Professor Bryan McFarland* (Liverpool) outlined his current practice in this ever-present problem, and stressed the value of early diagnosis. Manipulation followed by plaster-of-Paris immobilisation was used in the infant. In older children, when reduction by closed means could not be effected, he preferred the Colonna procedure. He emphasised the poor prognosis in bilateral dislocations.

Clinical meetings—At the Royal Alexandra Hospital for Children, Camperdown, *Mr D. Whiteway* showed three children suffering from congenital dislocation of the hip; *Mr A. F. Dwyer* demonstrated the results of treatment of slipped femoral epiphysis by cervical osteotomy; *Mr J. Roarty* and *Mr T. Claffey* showed subcapital fractures of the neck of the femur in children; *Mr J. Ellis* showed a modification of the Denis Browne splint for congenital dislocation of the hip. *Mr R. Middleton* presented two children with resistant talipes equino-varus treated by elongation of the tendo calcaneus, posterior capsulectomy and transplantation of the tibialis anterior to the outer border of the foot, and *Mr R. Wherrett* showed a similar case. *Mr B. Bracken* showed three patients with osteomyelitis which had once again become a problem in Sydney because of the emergence of highly virulent staphylococcus resistant to antibiotics. *Mr A. Watts* and *Mr C. M. Maxwell* showed three children with Perthes' disease. Mr Watts used ambulant methods, Mr Maxwell the traditional long period of immobilisation on a frame. The audience was unable to appreciate any difference in the end results.

At the Prince of Wales Division of the Sydney Hospital *Mr H. R. T. Hodgkinson* showed a patient with an extensive haemangioma of the tibia and another with bilateral fractures of the femoral neck due to osteoporosis associated with a parathyroid tumour which had been successfully removed. *Mr B. Bloch* showed an osteoclastoma of the left tibia. *Mr W. Stening* presented two patients with spondylolisthesis, one of whom had had an anterior bone graft with complete relief of symptoms. *Mr A. R. Hamilton* showed an interesting family of father, son and daughter, all suffering from bilateral dislocation of the patellae. *Mr J. Hoets* showed a man of thirty-four who, at the age of ten, had had osteomyelitis of the head of the femur with a subsequent ankylosis in poor position. Osteotomy had relieved the deformity for some years but recently he had suffered intractable backache for which a successful spinal fusion had been performed. *Mr J. Royle* showed a patient with intractable epicondylitis of the elbow successfully treated by the operation of denervation. *Mr A. Hodgkinson* showed a patient who had recently undergone an Austin Moore replacement arthroplasty for osteoarthritis of the hip and two patients who had undergone intramedullary nailing of the tibia for segmental fractures. *Mr A. I. Rhydderch* showed a patient with a chordoma of the body of the second cervical vertebra. The greater part of this had been excised; and the spine was subsequently stabilised by a posterior bone graft. A second patient had had Steindler's flexorplasty of the left elbow for paralysis from anterior poliomyelitis. *Mr B. Bloch* exhibited numerous slides and sections of current studies on the epoxy-resins for the bonding of fractures.

At St Vincent's Hospital *Mr E. West* showed a patient with a synovioma of the forearm; *Mr K. Cohen* presented a case of calcinosis; *Mr A. Rhydderch* showed some slides demonstrating firm bony fusion at the C.5–6 disc space after an anterior excision of the disc and bone graft; *Mr A. R. Hamilton* showed an extensive haemangioma of the knee; *Mr R. Nicholson* showed slides of myositis ossificans of the buttock which, in the early stages, had been thought to be a sarcoma; *Mr J. H. Cloke* showed films of a patient who had sustained a fracture-dislocation of the lumbar spine with severe separation of the vertebral bodies successfully realigned without any neurological complications. *Professor Bryan McFarland* showed a film of the Thomas's splint. *Mr W. R. Gayton* showed slides of patients, one suffering from an extensive fibrosarcoma of the plantar fascia, another of a successful reduction of a dislocation of the shoulder of six weeks' duration. *Mr T. King* issued a warning of the dangers attendant upon discography and told of two patients who had developed extensive arachnoiditis. *Mr C. Greaves* showed slides of a patient suffering from an osteoclastoma of the femur. The session concluded with a short film by Mr Gayton showing an extremely good end-result from an Austin Moore replacement arthroplasty.

ANNOUNCEMENTS

BRITISH ORTHOPAEDIC ASSOCIATION

MEETINGS IN 1962

It has been necessary to rearrange the Meetings of the British Orthopaedic Association for 1962. The revised arrangements are as follows. The spring meeting will be held in Canterbury and Margate on May 3–5 (not in Copenhagen as previously announced). The autumn meeting will be held in Copenhagen, probably in the first week of September.

Those wishing to present a paper at the Canterbury and Margate meeting should supply an abstract of about 400 words (five copies) to the Honorary Secretary, British Orthopaedic Association, 47 Lincoln's Inn Fields, London, W.C.2. The closing date for receipt of abstracts is January 3, 1962.

Any surgeon who is proposing to submit a paper for possible presentation at the meeting in Copenhagen should communicate with the Honorary Secretary as soon as possible, and in any case not later than the end of January, 1962.

TRAVELLING SCHOLARSHIP

The British Orthopaedic Association invites applications from its Fellows, Members and Associates practising in the United Kingdom for a Travelling Scholarship in orthopaedics of about three months' duration to visit centres in Great Britain or other European countries. The sum available will be £350.

Twenty typewritten copies of the application should be sent to the Honorary Secretary, British Orthopaedic Association, 47 Lincoln's Inn Fields, London, W.C.2, setting out the object of the proposed visit, the proposed itinerary, and previous clinical experience and contributions to research, and should give the names of two referees, who must be Fellows of the Association. The closing date for receipt of applications is October 31, 1961.

TRAVELLING FELLOWSHIPS TO NORTH AMERICA, 1962

Applications are invited from Fellows, Members and Associates of the British Orthopaedic Association for election as Travelling Fellows to visit orthopaedic centres in the United States and Canada, during a tour of approximately eight weeks (including the time of transatlantic travel). Four Travelling Fellows will be appointed by the President of the British Orthopaedic Association on the recommendation of the Executive Committee. In the election, preference will be given to senior orthopaedic registrars and to surgeons who have gained consultant orthopaedic appointments within the last few years. The party will probably leave this country in May 1962.

Twenty typewritten copies of the application should be sent to the Honorary Secretary of the British Orthopaedic Association, 47 Lincoln's Inn Fields, London, W.C.2. The application should state name, address, telephone number, age, qualifications, medical school, and present appointments, together with an outline of previous experience and academic or literary achievements. The application must be supported by a referee who is a Fellow of the Association. The closing date for receipt of applications is October 31, 1961.

If any young surgeon who is not already an Associate of the British Orthopaedic Association wishes to apply he should communicate with the Secretary of the Association at 47 Lincoln's Inn Fields, London, W.C.2 (HOLborn 3474), who will send the necessary forms.

LIMB FITTING CENTRE, ROEHAMPTON

AUTUMN COURSE

The Autumn course for Orthopaedic Consultants and Senior Registrars on the Rehabilitation of the Amputee will be held from October 30 to November 3, 1961, at the Limb Fitting Centre, Queen Mary's Hospital, Roehampton, London, S.W.15. Applications should be made to the Principal Medical Officer, Artificial Limbs and Appliances (Med. 7), at that address.

AUSTRALIAN AND NEW ZEALAND ORTHOPAEDIC ASSOCIATIONS

The Australian Orthopaedic Associatian and the New Zealand Orthopaedic Association will hold a joint meeting at Wairakei, North Island, New Zealand, from February 5 to 8, 1962. This is the first joint meeting of the two Associations. Visitors will be most welcome. Information about accommodation may be obtained from Mr John Saunders, Honorary Secretary, New Zealand Orthopaedic Association, Kelvin Chambers, 16 The Terrace, Wellington, New Zealand. The Honorary Secretary of the Australian Orthopaedic Association is Dr Richard Hodgkinson, 147 Macquarie Street, Sydney, N.S.W.

UNIVERSITY OF MINNESOTA

MEDICAL CONTINUATION COURSE

A medical continuation course on " Orthopaedics for Orthopaedic Surgeons (Hand Surgery) " will be given at the Centre for Continuation Study, University of Minnesota, Minneapolis, Minnesota, from November 16 to 18, 1961. Further information may be obtained from the Director, Dr W. Albert Sullivan, Jun., M.D., the University of Minnesota, the Medical School, Minneapolis 14, United States of America.

Book Reviews

Orthopaedics. By George PERKINS, *M.C.*, M.Ch., F.R.C.S., Consulting Orthopaedic Surgeon at St Thomas's Hospital, London; Consulting Surgeon, Rowley Bristow Orthopaedic Hospital, Pyrford. $9\frac{1}{2} \times 7$ in. Pp. xiv+976, with 577 figures. Index. 1961. London: University of London, The Athlone Press. Price 126s.

This new text-book on orthopaedic surgery is produced by a famous orthopaedic surgeon, now retired, but who believes that at the end of an active career he has acquired some knowledge worthy of being handed on. The author is dogmatic; a dogma is never universally acceptable, and he says, " I expect many orthopaedic surgeons to disagree with my views." He has underlined the principles of operations rather than the methods, while " pathology is skimmed over, since, in orthopaedics, it is in its infancy."

The book is on a regional basis, but there are additional sections on bone, nerves, and one on muscle, tendon and synovium. In the description of Paget's disease the belief is expressed that heart failure as a complication may be a coincidence. Ultra-violet rays are recommended for pain.

There is a good chapter on manipulative surgery and in it the claim is made that a prolapsed disc may be replaced by manipulation, and this is the logical method of treatment especially as only three out of four are cured by operation. The author states that bone-setters do sometimes cure recurrent dislocation of the shoulder by breaking down adhesions.

In degenerative forms of arthritis relief is claimed for lactic acid injection into the joint, which is said to produce its benefit by increasing the lubrication of the joint, by its anaesthetic effect, and by altering the pH of the joint fluid, but in any case it does diminish pain " in some mysterious manner."

For the " frozen shoulder " rest in a sling is advised, but active movements are not encouraged. No mention is made of the association of biceps tendinitis, or, of course, anything about pathology. A new form of intra-articular arthrodesis of the tuberculous shoulder is shown in a good radiograph, where nature rather than the operation may eventually fuse the joint.

The views of the author on congenital dislocation of the hip are interesting. It is doubtful whether reduction should be attempted after the age of three since attempts at reduction after that lead to so much stiffness and pain. Though some surgeons rely on traction in abduction for children before the age limit, most surgeons, it is said, reduce by manipulation under anaesthesia; this is recommended, and a description is given of the method used by Denucé. Maintenance is by a frog plaster case. The complications of congenital dislocation of the hip are well described, as would be expected.

For the retention of a slipped upper femoral epiphysis a Smith-Petersen nail is still used. For the operative relief of symptoms in osteoarthritis of the hip arthrodesis with osteotomy is the operation of choice, and osteotomy second only to arthrodesis, and, for the old, simple excision of the head. It is good to read that Lambrinudi's operation for claw foot is recommended even though it is " tedious and finicky." For hallux valgus excision of the metatarsal head has the advantage of removing the deformity, and a radiograph is shown of the operation. The removal of an important weight-bearing point apparently causes no worry. Another interesting operation for hallux valgus is shown in a radiograph—amputation of the fifth ray.

Ankylosing spondylitis is dealt with adequately, including a radiograph of a very good operation for kyphosis. In fusing a spine for tuberculosis the technique is standardised and two stout grafts are fixed to either side of the spinous processes by screws or bolts.

This is a beautifully produced volume and the illustrations are amongst the best in any text-book. The radiographs do not compare so unfavourably with the originals as the author suggests, and the small enlargements are a new feature and most helpful.

It is not clear for whom the book is written—probably for the undergraduate since there is little pathology or operative technique. The book as a whole, in any case, is rather too sketchy and controversial for the postgraduate as the examiner might not fancy all the fads that the author admits to in his preface.—Walter MERCER.

Surgical Treatment of Trauma. Edited by Preston W. WADE, M.D., with thirty-five other contributors. $9\frac{3}{4} \times 7\frac{1}{2}$ in. Pp. xii+779, with many figures (some in colour). Index. 1960. New York and London: Grune & Stratton, Inc. Price $26.50.

This book is, in the words of its editor, " a compilation of many lectures prepared by thirty-five different authors." It presents in written form the material of a postgraduate course given annually by the Cornell University Medical College, and the list of contributors is impressive. Every aspect of trauma is included—there is even a chapter on the treatment of mass casualties—and it is perhaps for this reason that the book falls short of the ideal. Inevitably, there is some repetition, and the standard of presentation is a little uneven. It may well be argued that so large a subject should not be dealt with in one volume, and it is certainly odd, for example, that the Colles fracture should receive thirty-four pages of attention, little less than that devoted to injuries of the abdomen and urogenital system. The criticism of an " omnibus " volume is that no one aspect of the problem can be fully dealt with, and in this book insufficient practical detail is included in some instances to make it as a whole a comprehensive work of reference. As a piece of entertaining reading for those interested or engaged in the treatment of accidents, however, it is admirable. Comparisons are odious, but the chapters on burns and on reconstructive procedures on the soft tissues are particularly attractive, and it is very good to see the question of full-thickness flap grafting given due attention. The editor himself has been responsible for some of the best chapters on fracture treatment, and, although the emphasis on metallic fixation is not in accord with British practice, there is much valuable instruction in this field. The book is profusely and well illustrated, and, as one would expect, excellently produced. —E. Mervyn EVANS.

Handbuch der Orthopädie. In Vier Bänden. Herausgegeben von Prof. Dr G. HOHMANN, emer. Direktor der Orthopädischen Universitäts-Poliklinik und Orthopädischen Klinik München; Prof. Dr M. HACKENBROCH, Direktor der Orthopädischen Universitätsklinik Köln; and Prof. Dr K. LINDEMANN, Direktor der Orthopädischen Universitätsklinik Heidelberg-Schlierbach. Band IV/Teil 1. Spezielle Orthopädie Untere Extremität. $10\frac{1}{2} \times 8$ in. Pp. xvi+740, with 751 illustrations in 428 figures. 1961. Stuttgart: Georg Thieme Verlag. Price DM 142.

This is the fourth volume of the monumental work being compiled by a large number of leading German orthopaedic surgeons.

This volume is mainly concerned with the hip and contains some notable works on the subject. Of particular note are the two studies by Professor Hackenbroch on the mechanics of the hip and on osteoarthritis. I have found the latter excellent and I would recommend it to all those who may still consider that orthopaedic surgery is nothing more than a glorified aseptic carpentry. The contribution of more than one hundred pages that Dr K. F. Schlegel dedicates to congenital dislocation of the hip is notable. The chapter is so well documented that its bibliography covers over twelve pages of closely packed references, many of which are of Anglo-Saxon works. Osteochondritis, infections, trauma and tumours of the hip region complete, with some more rare conditions, the material included in this, the largest part of the volume. Its last section deals with disorders of the femur and knee joint in chapters that are more concise but not without interest, particularly that on the knee joint by Dr Von O. Boos.

Going through the well printed pages of this book I have too often regretted that the author has kept his personal views so much to himself that the reader may be unable to detect them. While this seems objective and thus wise in general, the young trainee must be left at a loss on too many occasions about the relative importance of the factors involved. Despite this criticism, which cannot be applied to all the chapters, this work continues to be an outstanding contribution to orthopaedics whose influence is likely to spread outside the confines of Germany.—Joseph TRUETA.

Subtalar Arthrodesis in Poliomyelitis. A Clinical Study on Triple Arthrodesis with and without Simultaneous Tendon Transfer in 211 Adult Feet, including some cases of Lambrinudi's Arthrodesis for Drop-foot. By Ralf LINDHOLM. $9\frac{1}{4} \times 6\frac{1}{4}$ in. Pp. 117, with 26 figures and 28 tables. 1960. Helsingfors: Annales Chirurgiae et Gynaecologiae Fenniae, Supplement No. 97 to Vol. 49. Price not quoted.

This monograph from the Orthopaedic Hospital of the Invalid Foundation in Helsinki reviews the experience of the treatment of feet affected by poliomyelitis over the years 1943 to 1955.

The author first gives an excellent review of the historical development of stabilisation procedures and tendon transfers in the treatment of paralytic foot deformities. There follows an account of the pathogenesis of these deformities. The author's view that pes cavus is due to intrinsic weakness would not be universally accepted.

The main part of the work is a clinical review of 211 feet operated on by twenty-five different surgeons, under the general direction of the late Professor F. Langenskiöld. The majority were treated by a combination of triple arthrodesis and tendon transfer. The results were assessed by personal observation in 147 cases and on replies to a questionnaire in the remainder. Over the whole series 67·8 per cent of feet showed improvement; in the author's view 70·6 per cent of the failures were due to avoidable faults. The proportion of failures was highest among the feet with varus and equino-varus deformities, and lowest in those treated by Lambrinudi's drop-foot operation.

The main positive value of tendon transfer was seen in cases of equinus and equino-valgus deformity, where transfer of the peronei to the dorsum gave a useful power of active dorsiflexion in many cases. The negative virtue of preventing recurrent deformity was not clearly demonstrated. In only two cases was an undesirable effect of the tendon transfer noted.

One of the largest single causes of failure was non-union. Although the author does not think so, one wonders whether this can be attributed to the policy of doing the triple arthrodesis and the tendon transfer at the same operation.

This review is believed to be the only one of a large series of combined stabilisation and tendon transfer operations, and as such is of great importance to all who are interested in the problem of paralytic foot deformities.—Michael PILCHER.

Procedures in Vascular Surgery. By Richard WARREN, M.D., Clinical Professor of Surgery, Harvard Medical School. Illustrated by Helen C. LYMAN. 11×9 in. Pp. x+211, with many figures. 1960. London: J. & A. Churchill Ltd. Price 85s.

Dr Warren's book is an expansion of an outline prepared some time ago for the guidance of his Residents and contains, besides some instructional material, matters relating to policy, informational items, and "some sermonising" as he says.

He defines his field of vascular surgery as one where the surgeon performs intrathoracic, extracardiac vascular procedures and peripheral ones, but leaves cardiac surgery to another. The author describes only one method for each procedure without claiming its superiority but because he has found it effective.

The book might be divided into three—arterial operations, amputations and venous operations. Thirty-one operations are described. Each is made apparently simple by beautiful line and wash diagrams which must be extremely useful to the young operator. The letterpress is adequate without useless padding. The objective, the indications and contra-indications, the planning, the operation and after-treatment are written up in a few lines. The reviewer has nostalgic memories of the first lesion described—a co-arctation of the aorta. It is interesting to see the continual advances that are made in these operations, particularly newer methods by artificial replacements to restore continuity.

The section on amputations is well done, but it is interesting to see that Syme's amputation is not carried out as Syme did it, though it is good that the importance of retaining the position of the heel flap is emphasised. In amputating at the thigh the deep fascia is sutured but not the muscles, though current thought, especially of limb-makers, is that the extensors and flexors should be stitched to each other. There is a good section on early walking after amputation. The author recommends walking by the eighteenth day. It must be a shock for British limb-makers to read—"10th day: Temporary artificial limb arrives."

This is a well produced volume and as far as it goes will be of great use. The drawings are most instructive.—Walter MERCER.

Clinical Orthopaedics. Number 17—Clinical Physiology and Pathology of Bone. Editor-in-Chief, Anthony F. DEPALMA. With the assistance of the Associate Editors, the Board of Advisory Editors and the Board of Corresponding Editors. Pp. xii+387, with many figures and tables. Index. 1960. Philadelphia and Montreal: J. B. Lippincott Company. London: Pitman Medical Publishing Co. Price 60s.

The seventeenth volume of *Clinical Orthopaedics* has just been published. The book is designed for the publication of original articles offering significant contributions to the advancement of surgery. This issue is published as part of the celebration of the seventy-second birthday of Franklin Chambers McLean and the contributors are all associates or pupils of his, working on the frontiers of the field of bone.

The articles deal with or bear on the problem of musculo-skeletal disease in animals and in man, and have a direct bearing on orthopaedics in the broad sense of the word. An early chapter is devoted to the McLean campaigns for full-time Academic Medicine by the guest editor, Marshall Urist. "Success in practice will be measured not only in terms of your ability to deal with injury and deformity, but equally in terms of your grasp of the metabolic and systemic problems of bone that come to you," said McLean in a lecture to the American Academy.

There are some most interesting chapters on various aspects of the physiology of bone, the radio-isotope osteogram, isotope studies of bone salts, age changes in human bone (by Jenifer Jowsey), and many others. A short section on more clinical aspects concludes the book. This describes the Stone method of surgery for hallux valgus used by Dr Stone for at least fifty years, though its success as described has not yet reached this country. There is an interesting description of a lady from El Paso who at the age of 107 had a Frederick Thompson hip prosthesis inserted and who lived and is still alive two years after. Tough folk in El Paso!

This is a useful volume for those interested in clinical physiology and pathology of bone.—Walter MERCER.

Pathology of Tumours. By R. A. WILLIS, D.Sc., M.D., F.R.C.P., Honorary Research Fellow, University of Leeds; Consultant Pathologist to the Imperial Cancer Research Fund, London; Formerly Pathologist to the Alfred Hospital; Consultant Pathologist to the Austin Hospital for Chronic Diseases and Lecturer on the Pathology of Tumours in the University of Melbourne, Australia; Sir William H. Collins Professor of Pathology, Royal College of Surgeons, London; Pathologist to the Royal Cancer Hospital, London; and Professor of Pathology, University of Leeds. Third edition. 10×8 in. Pp. xvi+1,060, with 500 figures. Index. 1960. London: Butterworth & Co. (Publishers) Ltd. Price 105s.

Pathologists in this country and, indeed, all over the world have taken this great book to their hearts since its first appearance in 1948. Its successive editions have contrived to keep it up-to-date, without modification of its well-conceived original plan and with only a trivial increase in the number of pages. The present edition is bulkier than its forerunners simply because of the improved quality of the paper, to the great advantage of the photographic reproductions. The book, though primarily addressed to pathologists and research workers, is so practical and informative that, to the reviewer's knowledge, many surgeons have their own copy and testify to its value as a day-to-day work of reference.

The author has for many years been mainly engaged both as a hospital and as an academic pathologist on the study of human tumours, their diagnosis, histogenesis and behaviour. The book is a record of vast personal experience of these matters coupled with a comprehensive but critical reading of the world literature. Each chapter is accompanied by a long list of references, whose value is enormously enhanced by the helpful use of bold type for the authors' names and of full titles of articles or books that Willis has found particularly useful, important or original. The less clinical aspects of cancer research are presented in an eclectic manner in so far as they are judged to bear on the main issues of neoplasia in man, and the author's scholarship also ranges widely over the fields of embryology and general biology.

The volume comprises about a thousand pages of text, which include some 500 figures, mainly photomicrographs. The first 207 pages are devoted to what in this country is called the general pathology of tumours—definition, classification, experiments, statistics, comparative pathology, growth and spread. This section should be read in its entirety by anyone who assumes an interest in the properties of tumours. It is a wonderfully balanced and fully documented presentation of both old and new views. Next come about 400 pages on epithelial tumours of specified organs or parts. Each regional chapter presents what is known about the appropriate tumours in an orderly sequence of frequency, age and sex incidence, site, structure, behaviour and metastasis, although the section headings vary as occasion demands. The rest of the book is devoted to tumours of the connective tissues and of the nervous and haemopoietic systems and to teratomas, embryomas and less easily classified varieties of new growths.

The orthopaedic surgeon will find of direct interest, besides the opening chapters, about 120 pages on mesenchymal tumours, another fifty pages on peripheral neural tumours, and perhaps the fifty pages on teratomas. He may well consider the chapter on tumours of cartilage and bone too short and too general to be of great practical value, but he will probably already know the larger monographs in this field and he will not buy Willis's big book to learn specially about bone tumours. Willis's more general views on such subjects as the intermutability of mesenchymal tissues, the kinship of various mesenchymal tumours, the variants of fatty tumours and the truth about striped-muscle

tumours embody doctrines that are now essential to the proper understanding of connective tissue behaviour, not only in neoplasia, but in pathological reactions of all kinds. There are commendable chapters on tumours of synovial tissues and of the nerve sheaths and on angiomas.

The book is undoubtedly a classic. It must not be overlooked by anyone with either a philosophical or a practical interest in neoplasia. Here and there somewhat unconventional opinions are expressed rather dogmatically, but Willis made it clear in the preface to his first edition that it was his policy "to state plainly my own present opinions, even though these may have to be modified in the light of future experience." Indeed, he has modified them in successive editions or, as often as otherwise, outside experience has proved him right.—D. H. COLLINS.

A Catalogue of The H. Winnett Orr Historical Collection and Other Rare Books in the Library of the American College of Surgeons. Editor: Miss L. Marguerite PRIME. $10\frac{1}{4} \times 7\frac{3}{4}$ in. Pp. xxi+198, with 23 figures. 1960. Chicago: American College of Surgeons. Price $7.50.

Dr H. Winnett Orr, a much loved and distinguished surgeon, died in 1956 and bequeathed a remarkable collection of books to the American College of Surgeons. His well known work on compound fractures made his name known throughout the world. It was at Whitechurch Hospital, near Cardiff, in 1919 that the unhappy results of treatment and the long delay in treating of open fractures convinced him that frequent changes of dressings was an important factor in delaying healing. He had always been an admirer of H. O. Thomas's oft reiterated principle of "rest, uninterrupted and prolonged," and this he carried out in his new method by enclosing the fracture in plaster-of-Paris. Amid grave opposition he transported large numbers of American soldiers with compound suppurating fractures home in plaster, and in spite of the forebodings of disaster the patients did well.

He was lecturer on the History of Medicine at the University of Nebraska (1903) and his studies in preparation for his lectures had the effect of making him an ardent book collector. From 1920 till his death he regularly haunted the second-hand book stores of whatever city he might visit.

The Winnett Orr collection in the College Library consists of some 2,600 volumes and includes many rare old items, numerous publications marking eras in the history of surgery and orthopaedics, individual and collective biographies, and books pertaining to the history of institutions. Various writings of Galen appear in the list under dates extending from 1524 to 1856. Undoubtedly the most beautiful edition in this collection is the four-volume publication of Galen's complete works which appeared in 1561 and 1562. Nicholas Andry's original edition *L'Orthopédie* (1741) and the English translation (1743) are of great interest to the orthopaedic surgeon, as well as many others, numbering up to 400, on that special branch of surgery. The first two volumes of the *Transactions of the British Orthopaedic Society*, 1896 and 1897, are in the collection with a little footnote, "These two small volumes were obtained from Oxford, England, in 1938. I had made a long search for them because I knew that they were in existence but had never seen copies until this time."

The H. Winnett Orr collection in the College library has been divided into two sections. The first represents the rare books and classics. The second, and larger division, includes volumes on the allied fields of anatomy, physiology and general and orthopaedic surgery. The last was the speciality to which Dr Orr was particularly devoted and upon which his notes were most personal, reflecting, as they did, his principles and his experience as the speciality developed, as well as his affection for his former teacher and friend, Dr John Ridlon. Through Ridlon he acquired a knowledge of the personality of Hugh Owen Thomas and Sir Robert Jones, leading to the publication of his book on these great men.

This is not a mere catalogue for it contains many footnotes written by Winnett Orr himself on the books, notably those on Jones, Thomas, Steindler and even Scholl. This is a notable contribution and one of great value to authors, particularly on orthopaedic subjects.—Walter MERCER.

CONTRIBUTORS—AUGUST 1961

N. J. BLOCKEY, Esq., M.Ch.Orth., F.R.C.S., Royal Hospital for Sick Children, Glasgow, C.3, Scotland.

Professor RUTH E. M. BOWDEN, D.Sc., M.B., B.S., Royal Free Hospital School of Medicine, 8 Hunter Street, London, W.C.1, England.

Professor PAUL W. BRAND, F.R.C.S., Christian Medical College and Hospital, Vellore, India.

Professor D. A. CAMERON, M.D.S., Department of Pathology, University of Sydney, Sydney, New South Wales, Australia.

Professor D. H. COLLINS, *O.B.E.*, M.D., F.R.C.P., Department of Pathology, The University, Sheffield, 10, England.

M. B. DEVAS, Esq., F.R.C.S., 12 Richmond Road, Bexhill-on-Sea, Sussex, England.

Dr J. DUPARC, M.D., 6 Square Thiers, Paris 16, France.

DAVID K. EVANS, Esq., M.B., F.R.C.S., The Royal Infirmary, Sheffield, England.

E. MERVYN EVANS, Esq., F.R.C.S., Killay Croft, 339 Gower Road, Swansea, Wales.

R. S. GARDEN, Esq., M.Ch.Orth., F.R.C.S.E., 32 Ribblesdale Place, Preston, England.

A. W. B. HEYWOOD, Esq., M.Ch.Orth., F.R.C.S.E., 911 Medical Centre, Heerengracht, Cape Town, South Africa.

Dr IAN ISHERWOOD, F.F.R., D.M.R.D., Department of Radiology, Derbyshire Royal Infirmary, Derby, England.

G. C. LLOYD-ROBERTS, Esq., F.R.C.S., The Hospital for Sick Children, Great Ormond Street, London, W.C.1, England.

P. S. LONDON, Esq., *M.B.E.*, F.R.C.S., Birmingham Accident Hospital, Bath Row, Birmingham, 15, England.

I. G. MACKENZIE, Esq., M.D., F.R.C.S.E., Aberdeen Royal Infirmary, Aberdeen, Scotland.

Sir WALTER MERCER, F.R.C.S.E., Bidston, 7 Easter Belmont Road, Edinburgh, 12, Scotland.

Professor ERIK MOBERG, M.D., Sahlgrenska Sjukhuset, Göteborg, Sweden.

Dr SEPP MURR, M.D., Zürs a.A., Austria.

Dr JOHN R. NAPIER, L.R.C.P., M.R.C.S., Royal Free Hospital School of Medicine, 8 Hunter Street, London, W.C.1, England.

MICHAEL PILCHER, Esq., F.R.C.S., 138 Harley Street, London, W.1, England.

R. GUY PULVERTAFT, Esq., F.R.C.S., 27 Friar Gate, Derby, England.

Dr ROBERT B. SALTER, M.D., M.S., F.R.C.S.(C.), Hospital for Sick Children, 555 University Avenue, Toronto, Ontario, Canada.

J. SCHORSTEIN, Esq., F.R.C.S., F.R.F.P.S.(G.), 23 Whittinghame Drive, Glasgow, W.2, Scotland.

H. J. SEDDON, Esq., *C.M.G.*, D.M., F.R.C.S., Institute of Orthopaedics, Royal National Orthopaedic Hospital, 234 Great Portland Street, London, W.1, England.

A. J. SPENCE, Esq., F.R.C.S., Kirkcaldy Orthopaedic Hospital, Kirkcaldy, Fife, Scotland.

Professor JOSEPH TRUETA, M.D., F.R.C.S., Nuffield Orthopaedic Centre, Oxford, England.

Dr R. TUBIANA, M.D., 47 Quai des Grands-Augustins, Paris 6, France.

Dr CALVIN WELLS, Ph.D., M.R.C.S., L.R.C.P., The Old Hall, Mulbarton, Norwich, England.

Dr C. G. WOODS, B.Sc., M.B., Ch.B., Department of Pathology, University of Leeds, Leeds, England.

P. M. YEOMAN, Esq., F.R.C.S., Institute of Orthopaedics, Royal National Orthopaedic Hospital, 234 Great Portland Street, London, W.1, England.